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LOW IMPACT DEVELOPMENT BEST MANAGEMENT PRACTICES

COMPREHENSIVE OVERVIEW AND CASE STUDY

A Project

Presented to the

Faculty of

California State University,

San Bernardino

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in

Earth and Environmental Sciences

---

by

Graciela Rivera

June 2020

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ABSTRACT

This project paper is an overview of the different types of best management practices (BMPs) that can be applied within a Low Impact Development framework. Low Impact Development (LID) is a type of stormwater management implementation that is growing in popularity. It allows developments to manage stormwater by working within established ecosystems to lessen environmental impacts. The cost and effectiveness of these practices are examined. In the first chapter, a comprehensive summary to LIDs and BMPs is presented.

The costs and effectiveness of bioretention, biofiltraion and infiltration basins, as well as permeable pavements, were studied and compared. The facility case study, along with literature research, provides a current snapshot of the available information on the effectiveness of LID BMPs. .

Overall, permeable pavements had the highest performance in cost and efficiency, with costs ranging from $3 to $37 per square foot. Permeable pavements were also shown to have the highest potential for decreasing runoff and pollutants. Compared to other practices, their durability is high, but they require more maintenance over time. LID BMPs should be evaluated on a site-specific and case-by-case basis to determine the optimum costs versus benefits for a particular development project.

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CHAPTER ONE

BACKGROUND

Introduction

With urbanization and impervious areas rapidly increasing, erosion and degradation of estuaries and waterbodies continues to increase. Impervious surfaces and their effects could be reduced with the implementation of the practices of low impact development (LID) (*4*). The end result is an addition to water management by ensuring aesthetically pleasing development, as well as improved water quality. Best Management Practices (BMPs) are methods that are used to better manage stormwater runoff and its impact on receiving water quality. This is done with the ultimate goal of treating stormwater runoff as a water resource and not as wastewater. There are a variety of practices designed to manage different aspects of stormwater runoff. LID BMPs employ many controls to achieve their goals, such as bioretention, grassed swales, clusters, and public education (*17*). The BMPs that will be examined herein are bioretention areas, biofiltration swales and infiltration basins, and permeable pavements. The purpose of this study is to analyze the approaches to LID through literature research, analysis, and a detailed case study of a development with several types of BMPs.

Low Impact Development

Low Impact Development (LID) is rapidly becoming an alternative practice for managing stormwater in California, due to its notable success in other states. Interest in LID, rather than traditional stormwater control applications for residential developments, has increased in the past several years (*1*). In addition to management and water sustainability, LID practices aid in protecting and enhancing water supply and quality. Figure 1 below shows several examples of rain gardens and permeable pavements, LID practices implemented in Denver, Colorado.

Figure 1. Example of Rain Gardens and Permeable Pavements LID. (*2*)

Working interdependently with nature, LID is a process that allows developments to manage stormwater by integrating into the established ecosystems. Stormwater runoff, and the associated pollution problems, have two core issues: the magnitude of runoff from impervious surfaces and the amount of pollutants that are carried in the runoff. These two issues are evident in urban and urbanizing areas. These issues change the hydrology of the system, causing a variety of problems, including the loss and alteration of habitats, flood augmentation, diminution of biological diversity, and more frequent signs of sedimentation and erosion (*3*).

Impervious surfaces and their effects, such as rapid erosion and degradation of estuaries and waterbodies, could be reduced with the implementation of practices through LID (*4*). Unlike common stormwater management systems, LID intends to preserve and reconstruct the natural look and water infiltration by decreasing impermeability. This is done with the ultimate goal of treating stormwater runoff as a water source and not as a water waste. This goal can be accomplished by moving away from the collection of runoff into storm drains and pipes and alternatively collecting runoff into a municipal stormwater drainage facility for treatment and distribution. Traditionally, developments will build stormwater detention and retention basins to alleviate the effects of runoff peak flows. Low impact developments, with practices such as bioretention and permeable pavers, are implemented as a substitute or supplement to traditional stormwater detention and retention basins; this is because the LID practices have the ability to reduce runoff as well as pollutants, while encouraging infiltration (*6*).

As can be seen in Figure 2 below, these LID practices can also integrate plants and other greenery, adding to the aesthetics of the facilities that implement best management practices. What cannot be seen in Figure 2 is the low or hollow design of the biofiltration swale for the best collection of water.

Figure 2. LID Biofiltration Swale. (*5*)

Through natural tactics, LID treats stormwater immediately at the source by infiltration and evapotranspiration (*6*), thus maintaining the natural hydrology of the site. Generally, LIDs have the objective of treating pollutants in stormwater close to the source, as well as utilizing the natural hydrology of the development to lower any downstream impact from runoff (*7*). Staying close to the rainfall, LID proposes to mimic the natural hydrology that can then collect, retain, filter, infiltrate, and evaporate the runoff. The pre-development hydrology should be preserved in order to achieve LID key goals of managing stormwater and treating the runoff pollutants.

During the planning segment of implementation, LIDs require a more thorough site design than seen in traditional stormwater practices. The design should focus on preserving the site of disturbance (or needed disturbance), and ensure that soils, vegetation, and the aquatic systems are not impacted by the disturbed site. Traditional stormwater treatment only seeks to alleviate the peak flow rate of runoff; while LID has the same goal, it also seeks to preserve the volume of peak flows found on site before development (4).

By guiding the runoff toward pervious zones, pollutants can be captured and removed on site, rather than being transported downstream with the runoff. The removal is done through the increased water filtration provided by natural soil percolation processes. The end result is an addition to water management by ensuring aesthetic development and improved water quality. Collection methods (e.g., rain gardens, planter boxes, vegetated rooftops, landscape filter basins, porous and permeable paving, bio-swales) are employed as bioretention facilities. Typically, stormwater management systems found in LID are detached impermeable surfaces, swales and biofiltration areas, pervious pavers, bioretention, and infiltration basins. Many researchers have suggested that LID is the best way to alleviate the influence of urbanization on stormwater runoff (*1*). The implementation of LID techniques can help manage water by reducing the influence of developed areas, restore the balance of natural waters, restore hydrologic and ecological purposes, and avert pollution within a watershed.

Best Management Practices

Best Management Practices (BMPs) are controls that are used to better manage water pollution. BMPs have increased in popularity because of the favorable water quantity and aesthetic features that they produce. BMPs are meant to decrease the peak flow volumes of the runoff leaving a development and reduce pollutants (such as metals, hydrocarbons, nutrients, and total suspended solids) (8). These controls can range from specific methods, structures, or procedures that will help quantify water quality issues and work to minimize pollutants and erosion. Because developments have several land uses, BMPs can be implemented in parking lots, recreational areas, road ridges, depressed areas, floodplains and drainage channels, swales, rooftops, and underground water storage. Figure 3 is a collection of figures illustrating different types of BMPs in an LID setting. The selection of a site depends on variables like cost, safety, and upkeep (*9*).

Figure 3. A collection of Established BMPs in California. An Infiltration Basin (top left), Bioretention Area (top right and centered), Biofiltration Swale (bottom left), and Porous Asphalt (bottom right) (*12*), (*13*), (*14*), (*15*), (*16*)

BMP filtration methods process the rainfall and treat the pollutants at the site, which keeps the pollutants local and prevents them from traveling further through traditional stormwater processes. Therefore, BMPs are used to reduce and/or eliminate pollutants typically found in runoff before the stormwater reaches streams or rivers (*10*). Receiving waters and their health is a highly regulated area for point sources, but BMPs aid in efforts to strengthen water quality measures. Decreasing stormwater runoff through BMPs provides benefits like flood control, water conservation, public health fortification, wetland and ecosystem protection, and increased receiving waters quality. The United States Environmental Protection Agency has recommended systems that combine peak flow controls with the protection of natural waters to better sustain aquatic habitat properties (3).

Some of the critical issues that can be addressed with BMPs include environmental, social, and economical problems like flooding, erosions of stream banks and flat soils, and the chemical pollution of water (*11*). Chemical and biological pollutants harm aquatic life in receiving waters and may potentially affect public health. Erosion not only affects aesthetics but will also negatively affect wildlife.

Without the implementation of BMPs, negative effects—such as erosion, increased sediment within receiving waters, and the introduction of chemical and biological pollutants—will continue. Traditional practices for stormwater management, or peak shaving measures, have relied on runoff storage for mitigation. Typically, peak flow reduction measures have not been focused on the removal of pollutants. They have also shown many cases where hydrologic issues have been associated with these measures.

There are a variety of practices designed to manage different aspects of stormwater runoff. LID BMPs employ many controls to achieve their goals, such as bioretention, grassed swales, clusters, and education of the public (*17*). The BMPs that will be examined are bioretention areas, biofiltration swales and infiltration basins, and permeable pavements.

Bioretention Areas

Bioretention cells are depressed areas in developments that are created to accept stormwater and redirect it for controlled absorption. This method essentially works with gravity to retain water and treat runoff immediately following a storm. Bioretention cells are generally found in rain gardens, on rooftops, and within landscaping, both in residential and commercial locations, and are usually covered by mulch and decorated with perennials, trees, or other shrubs (4). Figures 4 and 5 below show 2 examples of bioretention BMPs. Figure 4 is in Downey, California; Figure 5 is from the Kaiser Permanente Hospital in Fontana, California.

Figure 4. Bioretention Cell in Downey, California. (*18*)

Figure 5. Bioretention BMP in Fontana, California. (*19*)

Aside from what bioretention BMPs do for stormwater, a development can still hold an aesthetic view by using plants and hardwood bark. Runoff is strategically guided to a shallow depression in the landscape where stormwater naturally collects. When a storm occurs, the runoff will collect in these areas and begin to percolate through the soil. The soil in the BMP is engineered to filter common pollutants as water runs through it, similar to a filtration column. The filtered water continues to collect and the overflow is then guided toward storm drains.

Treatment is not the only advantage to bioretention; it also provides a significant reduction in runoff, which decreases the chances of flooding, as well as reducing the amount of pollutants being washed into storm drains. This BMP treats the water, using retention methods for collection, which is then sent out to storm drains, aiding in the overall quality of the runoff.

<u>Biofiltration Areas and Infiltration Basins</u>

Biofiltration employs nature in the form of soil, plants, and microorganisms to filter pollutants from stormwater. Generally, this BMP is employed as a bioswale. When water is collected into this type of BMP, it slowly seeps into the engineered soil mix to begin the filtration process. The construction design of bioretention cells can differ in the methods used for treating stormwater runoff, but compared to a traditional concrete drainage ditch, it is a significant improvement. The vegetation treats the stormwater runoff by reducing the runoff rate and allowing it to settle, filter through the soil, and then infiltrate a swale or channel (*20*). The subsoil mix is designed to filter out common pollutants found in stormwater runoff, and also to be permeable enough to collect water at an effective rate. Vegetation removes the larger pollutants, like trash or sediment. The engineered soil has properties that filter in a way similar to an ion-exchange column, attracting pollutants away from the water. The microorganisms found in the system biologically break down organic pollutants from water by creating a biofilm to capture and break down these pollutants. Biofiltration swales are designed not only to treat the stormwater, but to capture stormwater at a velocity congruent to the flowrate. These areas are generally large and leveled recessed areas designed to collect large volumes of water. Pollutants carried by stormwater are biologically broken down by the vegetation in the channels that capture stormwater. As an added benefit, the rate and amount of runoff is reduced swiftly by biofiltration swales (*21*). The swales are planted with a variety of vegetation intended to collect large items from stormwater runoff such as trash, sediment, and oil-based pollutants. During a storm, the runoff collects in the BMP and permeates at a slow rate. Filtration, in collaboration with settling sediment and infiltration, will begin to treat the stormwater for pollutants usually found in runoff. Following the removal of these pollutants, the water tends to run through at a faster rate. Unlike bioretention BMPs, bioswales do not reduce the quantity of runoff entering or leaving the site, because pipes buried below this BMP transport the treated water offsite and into the traditional stormwater system. Figure 6 shows an example of an established biofiltration swale in Oxnard, California.

Figure 6. Biofiltration Swale in Oxnard, California. (*18*)

Infiltration basins are small, shallow, and bowl-like basins specifically designed to collect stormwater into the soil through infiltration. Infiltration basin designs can vary by region, due to the nature of site soils, which also depend on the condition of the pre-development. Infiltration basins differ from detention basins, in that infiltration basins lack design measures and standards. The characteristics of the soils on a site pose the greatest concern regarding this BMP design process (8). Due to their shape, they are like small pools that are designed to use permeable soil to collect stormwater and infiltrate it into the groundwater. These BMPs are generally referred to as recharge basins, due to their ability, among other applications, to recharge the groundwater beneath them. Infiltrations basins also assist in the treatment of the collected water as it flows to surrounding waterbodies; it achieves this by capturing the stormwater runoff and averting floods and erosion attributed to downstream flow. Infiltration basins stand out from other BMPs in their effectiveness by not only removing pollutants from the runoff but also decreasing the magnitude of the flow downstream. The water collected in the basin cannot be removed or released, except through natural processes, which decreases the flowrates downstream. The water can only be evaporated, infiltrated, or overflowed during a major flood. Due to soil requirements by certain sites, infiltration basins can have the largest number of problems with installation. An example of an infiltration basin is shown in Figure 7.

Figure 7. Example of an Infiltration Basin. (*18*)

Unfortunately, Infiltration basin BMPs have shown the least amount of success compared to other stormwater management practices (*22*). Although infiltration basins might have a difficult application and have shown little success, they have become the most popular, due to their many functions in water retention, water quality, and groundwater recharge. Figure 8 and figure 9 show more variation in the infiltration and biofiltration basins. Figure 8 shows a small infiltration basin that has grass planted in and around the basin. Figure 9 shows a small biofiltration basin that has more plants located within the basin than the previous example.

Figure 8. Grassy-Swale Infiltration Basin. (*23*)

Figure 9. Image of an Implemented Bioswale. (*24*)

Permeable Pavements

Permeable pavements, also known as pervious pavements, are BMPs specifically designed and utilized to control stormwater runoff on paved areas. Typically, this BMP is used to replace parking lots, sidewalks, driveways, and emergency lanes, due to its defined function of readily collecting stormwater as part of an LID (6). Figure 10 shows an example of a permeable pavement BMP implemented in Redlands, California.

Figure 10. Pervious Pavement in Redlands, California. (*18*)

Permeable pavements have the potential to be popular due to their ability to replace impermeable surfaces, which is usually the greatest surface area in a development. Generally, paved surfaces are impervious, meaning that when rain falls, it will land on the surface and it will collect as runoff through stormwater and flood control measures. With permeable pavements, the water will infiltrate through the pavement to the ground below; this will then decrease the amount of urban runoff, since the water will percolate through the ground, imitating natural processes (*25*). Adding infiltration abilities to developments allows LID to serve as a stormwater management system by reducing the stormwater runoff significantly. The removal of pollutants from impermeable surfaces has been successfully seen in low impact developments, specifically permeable pavements (*26*), (*27*). These pavements have been previously used in developments to ensure, control, and quantify water quality. Figure 11 shows permeable pavements are typically applied to parking lots, walkways, and sidewalks, but can easily replace any traditional pavement. Both private developments and municipal stormwater programs can implement permeable concrete.

Figure 11. Pervious Asphalt Basketball Court. (*18*)

Porous pavement is comprised of compact sand or gravel that readily allows water to permeate through. Clogging is dependent on the incoming pollutants. The clogging can happen since these pavements function to collect particulate matter from filtering runoff. The size distribution of the particles and the pores are both important in determining how to implement this LID (*28*). Like any filter, the particles that pass through depend on their size, as well as the soil composition and its affinity for certain pollutants. In addition to the water quality benefits, permeable pavements decrease the need for infrastructure to guide large quantities of runoff by allowing it to flow through to the soil below. As stormwater flows through the pavement, it enters a filtration area with treatment soil. There are many designs and variations of permeable pavers, as well as soil combinations, which can now be implemented. The ultimate goal of infiltrating stormwater can be achieved in a series of ways through different types of pavers (4). Traditional stormwater collection systems would only be used during heavy rainfall when the rate of precipitation exceeds the infiltration rate.

Permeable concrete and asphalts have slight differences that should be taken into consideration before application. Permeable asphalt has a mix that is a lot harder to produce than the mix for porous concrete, but any installer can manage it due to its simple application. The reverse can be said for permeable concretes; these have a very simple production scheme, but they are harder to install and require certified, professional installment (*29*). Permeable pavements allow passage and filtration of water that would otherwise traditionally fall on impermeable surfaces and wash pollutants directly into storm drains.

LID BMP Case Studies

This project intends to examine and compare the data from several LID BMPs that have been implemented on one development site. The emphasis will be on comparing their costs and effectiveness. The facility, which requested that it remain anonymous, built several state-of-the-art LID BMP demonstration features in order to study their performance. These parameters include aesthetics, water quality, and stormwater runoff reduction. Because the case study facility requested anonymity, it will be referred to as "the Facility" for the purposes of this study.

Low Impact Development, Best Management Practices Case Study Facility

The case study facility is located in Riverside, California. It is one of the independent county facilities that focus on the county's flood topics, such as hazards, problems, flood plains, regulation, public education, and water conservation. The Facility granted access to all its data pertaining to the implementation of its LID BMP, including construction estimations, bids and actual costs, as well as the results from the analysis of water samples taken since implementation.

The Facility implemented several LID BMPs throughout its grounds. The BMPs implemented include planter boxes, porous asphalt and concrete, biofiltration, bioretention, and an infiltration basin. Not only does the Facility strive to provide better management of stormwater, but it also tests the efficiency of the different LID BMP systems.

Water quality and stormwater runoff reduction have been monitored at this site, since it was designed as a demonstration facility. Once the samples were collected, any subsequent flows were directed to the infiltration basin next to the monitoring facility. The long-term upkeep, operations, and any construction, were also observed at the site in order to properly record its findings (*30*). The data collected, thus far, from the Facility's LID BMP program, was assembled and allowed to be used for analyzing. The data was examined for the total cost and effectiveness of each BMP. The analysis was done to give a broad idea of multiple LID BMPs in one area and how they compare to each other.

CHAPTER TWO

FINANCIAL ANALYSIS

Low Impact Development Cost Analysis

Developers have to decide whether the cost of implementing an LID BMP is worth the financial disbursements. This section is a comprehensive literature analysis of the costs of implementing LID BMPs.

Cost Analysis

The implementation of LID BMPs, like everything else, has a cost. In an effort to motivate communities to implement these low impact developments best management practices, there is a need to understand and examine the total design life expenses of LID BMPs. There have been many studies associated with the effectiveness of LID BMPs in reducing runoff and pollutants from storm events in urban areas, but the economics of LID BMPs have not been well researched (*31*). Figure 14 shows the rain garden bioretention cell during construction; this is from the Facility's actual construction.

Figure 14. Bioretention Cell Construction. (*32*)

The cost evaluation is especially important to new and renovating developers. Implementation of LID practices is becoming a stormwater management requirement due to new NPDES permit requirements. The cost information for LID BMP is more necessary now than before due to the separate municipal storm sewer system (MS4) permits that govern California and require implementation of LID BMPs for new and remodeled developments (*33*). For developers who may not be able to meet the permit requirements, this information about cost and feasibility can also be used as a basis for comparing compliance fees with costs for installing an LID practice. Aside from their effectiveness, LIDs must prove to be cost-efficient compared to traditional stormwater management practices for LIDs to continue being adopted (*31*).

Estimating the cost of BMP applications depends on more than just the class of LID BMP. Careful consideration of lot size, runoff quantities, as well as operations and maintenance (O&M) can draw a more detailed picture of the costs of implementation and the cost over time of the LID BMP systems.

Cost-Estimating Tools

In 2011, C. Dash Houdeshel, et al. (Department of Civil and Environmental Engineering, University of Utah), analyzed a cost-estimating tool designed for users implementing LID BMPs into their development. The tool was a spreadsheet, which was created as part of a report by the Water Environmental Research Foundation (WERF), in collaboration with the United Kingdom Water Industry Research (UKWIT) and with funding from the Environmental Protection Agency (EPA), which was designed to be used to estimate the whole-life cost (WLC) of LID BMPs. The BMPs in the cost-estimating tools are both traditional and for low-impact development; they include retention and detention ponds, swales, and permeable pavers. Agencies that had completed BMP projects were used to derive and create the spreadsheets with equations for capital costs of each BMP (*31*).

Figure 15 shows a blank WERF worksheet developed for determining the 'Capital Costs' of pervious pavements. Because there is potential for many scenarios, the models found in the spreadsheets will vary significantly in both the cost and the design of a BMP.

	A	B	C	D	E
1	**Permeable Pavement**		**Choose Capital Costing Option**		
2	**CAPITAL COSTS**		**A**	**Total Facility Cost**	**$ 28,780**
3	**Site Name:**		**"A"** - Simple Cost based on System Type		
4	**Site Location:**		**"B"** - User-Entered Engineer's Estimate		
5					
6	**Method A: Simple Cost based on Drainage Area**				
7	**Cost based on Drainage Area**		Cost per Acre of DA Treated		(Chosen option)
8			Model Default	User	
9	User Selected **ASPHALT** Permeable Pavement			Entered Sheet 1	1
10	Surface Area of Permeable Pavement System (ft2)			Entered Sheet 1	21,780
11	User Selected HIGH Permeable Pavement			Entered Sheet 1	H
12	Permeable Pavement Cost per square foot		$1.00		$1.00
13	**Base Facility Cost** (rounded up to nearest $100)		$ 21,800		**$ 21,800**
14	Engineering & Planning (default = 10% of Base Cost)		$ 2,180		$ 2,180
15	Land Cost		$ 0		$ 0
16	Other Costs		$ 0		$ 0
17	Contingency (default = 20%, rounded up to nearest $100)		$ 4,800		$ 4,800
18	Total Associated Capital Costs (e.g., Engineering, Land, etc.)				**$ 6,980**
19	**Total Facility Cost**		**$ 23,980**		**$ 28,780**
20	**Suggestion: Use higher or lower Per Unit Costs to reflect higher or lower regional construction costs.**				
21					
22	**Method B: User-Entered Engineer's Estimate**				
23	Select from the following list, as applicable to the project or facility type; add items where necessary.				
24	**Total Facility Base Costs**	Unit	Unit Cost	Quantity	Cost
25	Mobilization	LS			$ -
26	Clearing & Grubbing	AC			$ -
27	Excavation/Grading	CY			$ -
28	Haul/Dispose of Excavated Material	CY			$ -
29	Subsoil Preparation	SY			$ -
30	Impermeable Liner	SY			$ -
31	Rock Media	SY			$ -
32	Permeable Media	SF			$ -
33	Outflow Structure/Pipe	LS			$ -
34	Energy Dissipation Apron	LS			$ -
35	Revegetation/Erosion Controls	SY			$ -
36	Traffic Control	LS			$ -
37	Signage, Public Education Materials, etc.	LS			$ -
38	Other				$ -
39	Other				$ -
40	**Total Facility Base Cost**				**$ -**
41	**Associated Capital Costs**	Unit	Unit Cost	Quantity	Cost
42	Project Management				$ -
43	Engineering: Preliminary				$ -
44	Engineering: Final Design				$ -
45	Topographic Survey				$ -
46	Geotechnical				$ -
47	Landscape Design				$ -
48	Land Acquisition (site, easements, etc.)				$ -
49	Utility Relocation				$ -
50	Legal Services				$ -
51	Permitting & Construction Inspection				$ -
52	Sales Tax				$ -
53	Contingency (e.g., 30%)				$ -
54	**Total Associated Capital Costs**				**$ -**
55	**Total Facility Cost**				**$ -**

Figure 15. WERF Permeable Pavements Worksheet. (*34*)

Since the implementation of a BMP is site and goal specific, there has to be a distinctive flexibility within the worksheets. In order for a user to compensate for any specificity required by a project, flexible aspects were embedded into the spreadsheets. These aspects include: Climate changes, regulations, and cost discrepancies in materials and labor (*31*). Agencies, as well as developers, have many benefits within the cost-estimating whole-life-cost spreadsheets; this includes a calibrated form of reporting, method for system designs, and estimates in order to adequately plan a project. Besides the project goals and location, a project will also be affected by its own scale. The scale would potentially also affect the estimation of supplies and labor necessary for any given project. Limitations in the program include the variation of project types and sizes, as well as a lack of confirmable cost information. With this obstacle in mind, creators of the whole-life-cost spreadsheets took into consideration suitability to gauge a project's costs. In addition to the skills necessary for any project, developers must take into consideration the variations in costs for labor and materials, which range from volunteer work to high-cost professional construction. Limitations may occur during implementation as far as the options for materials and labor for larger projects (*31*). The worksheets created took into careful consideration the probable disputes for having an automated way to estimate whole-life costs; this consideration led the creators to make each model separately, and the designs were implemented independently from one another. The infrastructure cost of an LID practice will vary, just as the design considerations do. Having spreadsheets as a tool allows any user to modify the cost information in order to derive a more accurate cost, and also to compensate for the discrepancies. During the planning portion of a LID project, these tools assist in not only cost estimating but also to bring to light any factors that had not been previously considered (*31*). Figure 16 shows some of the graphs developed as an analysis tool following cost input. The graph on top shows the initial costs of input and then show that overtime there is little to know cost associated with the BMP until replacement or upgrades required approximately 35 years after development. The second graph shows that over time the value of the implemented BMP increases and then increases briefly, but sharply at the same 35 year mark to account for upgrades and improvements.

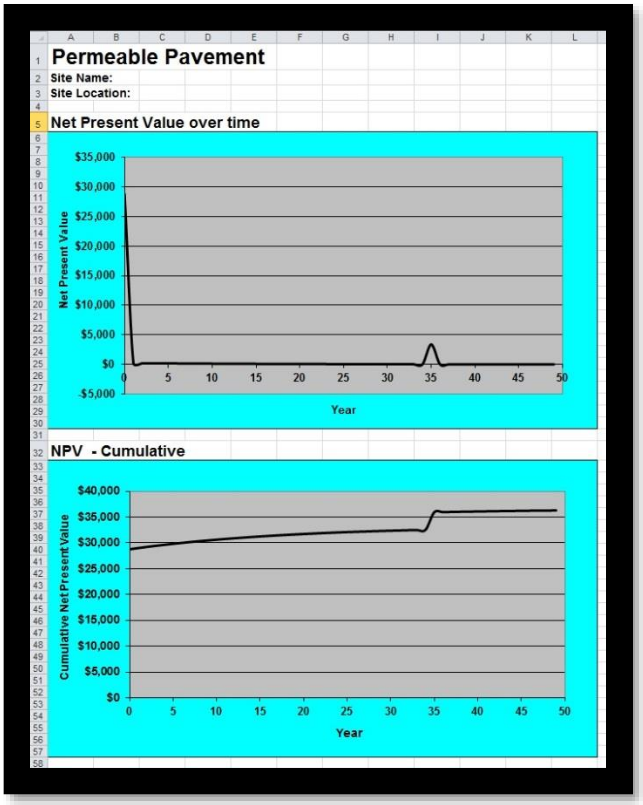

Figure 16. WERF Graph Outputs. (*34*)

Additionally, the tool assists agencies and developers in sharing the information regarding costs. There is room for improvement in the decision-making implementation of LID practices through these models by filling in the gaps of the information available (*31*). Having the ability to simplify the cost analysis in a project allows other aspects of the planning stage to take precedence and simplify the implementation of LID BMPs for developers and agencies.

Orange County

In order to adequately quantify the cost of LID BMP implementation, Orange County analyzed the cost by estimating different cases of LID applications. They used the most common scenarios that were seen throughout the county. In order to properly evaluate the correct LID BMP needed for a site, the feasibility of infiltration needs to be examined. This includes the infiltration rate, geotechnical issues, and pollutant presence. Following a feasibility analysis, the reliability and demand for sustainable water must also be gauged for LID BMP implementation (*33*). The following figures (Figures 17 - 19) have been extracted from the study done by the County of Orange to demonstrate a cost analysis of BMPs. The first is a summary of the installation, operations, and maintenance costs. The second shows the different LID BMP options and their estimated costs. The last shows the projected costs over 20 years. This analysis studies the detailed cost of implementation, as well as four different cases that involve different sets of LID BMPs based on necessity.

Table 1. Summary of LID BMP Installation and O&M Costs

		Installation and O&M Costs of LID BMP Types Found in Literature						
		Square Foot of LID BMP		Gallon Managed by LID BMP		Annual O&M as Percentage of Construction Cost		
Category	LID BMP Type	Low	High	Low	High	Low	High	Sources
Infiltration	Trench	$14	$43	–	$1	5%	20%	1, 2, 3, 4
Infiltration	Basin	–	$15	$1	$3	1%	10%	4, 6, 7
Infiltration	Planter	$25	$65	–	–	–	–	2
Infiltration	Gallery (pipe, chamber, crate)	–	–	$1	$3	–	–	8
Infiltration	Pervious asphalt/ concrete	$3	$27	–	–	1%	2%	1, 2, 6, 9
Infiltration	Pervious concrete joint pavers	$8	$37	$15	$22	1%	2%	2, 6, 7, 9, 10
Infiltration	Reinforced grass/ joint pavers	$2	$24	–	–	–	–	2, 9
Harvest and use	Cisterns	–	–	$1	$7	–	–	7, 8, 11, 12
Green roof	Extensive	$7	$325	$22	$46	–	–	6, 7, 9, 10, 13
Green roof	Intensive	$16	$522	$46	$64	–	–	6, 7, 10
Biofiltration	Biofilter and bioretention	$2	$69	$1	$6	1%	11%	1, 2, 4, 5, 6, 7
Biofiltration	Vegetated/grass swale	$1	$41	$1	$3	4%	7%	1, 2, 4, 6, 7, 10
Biofiltration	Flow-through planter	$26	$69	$3	$5	–	–	2, 6, 7, 9
Biofiltration	Rain garden	$3	$17	$3	$6	–	–	7, 9, 10

Notes:
All values are adjusted to November 2011 costs using *Engineering News Record Cost Index* (LA 20-city index) and rounded to nearest dollar.

Data sources:
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Figure 17. Summary of Costs Extracted from Cost of LID. (*33*)

Table 2. Summary of Case Study Types, Project Sizing Details, and LID BMP Combinations				
	Case Study Types			
	Commercial Office Complex	Single Family Residential	Urban Mixed-Use Commercial/Residential	Commercial/Retail Center
Surface Area (square feet unless noted)	**Case Study 1**	**Case Study 2**	**Case Study 3**	**Case Study 4**
Total project area	43,560	435,600	6,200	540,144
Total impervious area	39,204	217,800	5,600	486,130
Rooftop impervious area	22,000	91,000	5,600	150,000
Ground-level impervious area	17,204	126,800	400	336,130
Total pervious area	4,356	217,800	200	56,715
Total landscape area	4,356	152,460	200	56,715
Total parking/road access/hardscape area	12,848	130,680	0	321,386
Total project impervious area (percent)	90	50	90	90
Design capture volume (gallons)	19,000	120,000	2,800	218,175
Rooftop volume (gallons)	9,000	50,000	2,600	67,300
LID BMP Combinations	Infiltration basin Infiltration pavers Cistern (1, 2) Cistern & green roof (1) Biofiltration	Infiltration basin Infiltration pavers Cistern (1) Cistern & green roof (1) Biofiltration	Infiltration pavers Cistern (1) Green roof Cistern & green roof (1) Cistern & green roof (2) Biofiltration	Infiltration basin Infiltration pavers Cistern (1) Cistern & green roof (1) Biofiltration

Notes:
1. Cistern water used for landscape or green roof irrigation (if applicable) using a pressurized system with potable backup and backflow prevention
2. Cistern water used for landscape or green roof irrigation or indoor toilet flushing using a pressurized system and requiring treatment, with potable backup and back flow prevention

Figure 18. Summary of Case Study Types Extracted from Cost of LID. (*33*)

Table 3. Summary of Case Study LID BMP Installation and 20-year Operation and Maintenance Costs				
	Sum of Capital and 20-Year O&M Costs			
	Case Study Types			
	Office	Residential	Urban	Big Box
LID BMPs Evaluated	**Case Study 1**	**Case Study 2**	**Case Study 3**	**Case Study 4**
Infiltration basin	$76,300	$228,200	-	$322,000
Permeable pavers	$110,400	$414,000	$50,220	$695,500
Cistern: outdoor irrigation	$226,600	$814,460	-	$994,000
Cistern: outdoor irrigation & indoor use	$282,600	-	$136,000	-
Green roof	$922,700	$1,855,520	$353,100	$4,132,000
Biofiltration	$106,470	$463,400	$57,400	$422,870

Figure 19. Summary of 20 yr Projected Costs Extracted from Cost of LID. (*33*)

Orange County used many external sources to create the “Summary of Installation and O&M Costs” (*33*), which gives low and high estimates for different types of LID BMPs. The categories used to analyze costs in this study began with the types of practices, then a low and high estimate of the cost. The cost is shown in one of two ways: the cost per square footage or per gallon of stormwater that can be managed by given BMP. Using the 20-city Engineering New Records Construction Cost Index for Los Angeles, California, the costs were altered to reflect inflation increases, found in figure 17 (*33*). A bioretention rain garden can range in cost from $3 to $17 per square foot of application and will cost from $3 to $6 worth of managed stormwater per gallon. The annual cost of operations and management, in percentage of the construction cost, ranges from 5% to 20%. A biofiltration swale shows that each square foot varies in prices from $1 to $41 to implement, and can cost from $1 to $3 per gallon of managed runoff. The operation and maintenance cost for a bioswale ranged from 4% to 7% of the construction cost. Permeable pavements (porous concrete or asphalt) had a cost of implementation range from $3 to $37 for each square foot and can possibly cost $15 to $22 per gallon of managed stormwater. Their annual cost to operate and maintain was shown to be between 1% and 2% of the total construction cost. An infiltration basin, in this study, projected a cost of about $15 and from $1 to $3 per gallon in stormwater management. For operation and maintenance of an infiltration basin, the annual cost ranged from 1% to 10% of the construction costs. Orange County created four scenarios in BMP usage and necessity to analyze the prices. For example, the first case study created in this article was based on a commercial office with a total surface area of 43,560 square feet. The total cost for implementation of an infiltration basin, infiltration pavers, a Cistern water collection system, a green roof, and a biofiltration practice would give an estimated cost total at $1,725,070 for the entire project (*33*).

It was concluded, based on a range from $1 to $70 per square foot to apply LID BMPs, that the least expensive LID BMPs to employ are infiltration and biofiltration BMPs. Compared to biofiltration swales, planters on the curb-side, and pavers systems (which are generally more costly), the infiltration BMPs were shown to be somewhat more costly to install; however, they are less expensive in the long term, due to their lower operation and maintenance cost (*33*). The same can be said for infiltration and biofiltration LID BMPs when the gallons of runoff managed are observed. In an infiltration basin, the costs range from $1 to $5 per gallon compared to the Biofiltration BMP, which ranges from $16 to $522 per gallon of stormwater managed. Porous pavements were shown to have the simplest operation and maintenance requirements at the site.

The green roof planters were shown to be the most expensive BMP to install and maintain (*33*). Green roof planters are not being recommended in the Orange County MS4 permit; therefore, a full investigation on green roofs was not shown in the study.

Biofiltration and soil infiltration systems are similar, in that their operation and maintenance protocols require similar investigation to increase infiltration or biofiltration into the soil and plant media (*33*). Infiltration and biofiltration BMPs both require an assessment of the soil and its permeability prior to installation. These assessments will also take into consideration the treatment required to remove solids. Overall it is seen that biofiltration systems are the most cost effective BMP to install and maintain on any type of property. However, if that BMP cannot meet all of the runoff management needs prescribed in the corresponding MS4 permit, other BMPs will need to be applied as well. Figure 20 shows an example of how the Orange County BMPs will look after construction is completed.

Figure 20. Completed Low Impact Development in Orange County. (*35*)

Case Studies: Cost

In this section, the costs and financial data of both stages, construction and maintenance, of LID BMP implementation are fully examined. This evaluation of costs for the established LID BMPs at the demonstration facility will convey a broad illustration for comparison of the BMPs (*36*).

<u>The Demonstration Facility</u>

The massive LID BMP project that the facility underwent to develop its demonstration facility cost a total of $2.5 million to implement. Figure 21 shows the construction of the Pervious Asphalt BMP at the facility during the actual construction.

Figure 21. Construction of the Facility's Pervious Asphalt BMP. (*30*)

With that implementation cost came more than just the installation of BMPs. The facility implemented multiple types of BMPs, including: planter boxes, a biofiltration/bioretention swale, an infiltration basin, pervious pavements (concrete and asphalt), a green rooftop, and a water quality lab to collect storm samples to analyze the effectiveness of each BMP. The project was also comprised of aesthetically pleasing—yet water-conservative—landscaping throughout the demonstration facility, which included: water-friendly landscaping, artificial grass, picnic area décor, and more. While this means the cost for the demonstration facility includes more than just installation, it also shows the discrepancies between the models and “real life”. The models’ estimations do not include the costs for things like plants, which could be considered important additions by keeping the site aesthetically pleasing.

The plants and landscaping also installed at the demonstration facility supported its effort to have the LID BMP project imitate nature as closely as possible, not just through stormwater management but in appearances as well. The specific cost per BMP is not yet available for comparison. In Appendix B, a summary of the bid abstract is available, showing the breakdown of total costs for this project (*36*). After bids, the facility made negotiations and, eventually, construction estimations were accepted for a total of $2,439,489.30 (*36*).

Pervious pavements, and the implementations thereof, are specified in this abstract. The figure below shows a section of the abstract, as it pertains to permeable pavements. The complete abstract can be found in Appendix B.

Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

Item No. & Description	***Unit***	***Quantity***	ENGINEER'S ESTIMATE ***Unit Bid***	ENGINEER'S ESTIMATE ***Total Bid***	ASR CONSTRUCTORS, INC. ***Unit Bid***	ASR CONSTRUCTORS, INC. ***Total Bid***
21 REINFORCED CONCRETE PIPE	L.F.	200	$86.50	$17,300.00	$119.00	$23,800.00
22 3" CLASS 2 AGGREGATE BASE DRIVEWAY AND ACCESS RAMP	C.Y.	10	$108.00	$1,080.00	$50.00	$500.00
23 PERVIOUS PAVERS OVER 2" #8 OVER 3" #57 OVER 13" #2 STONE	S.F.	25,400	$15.35	$389,890.00	$7.55	$191,770.00
24 PERVIOUS PAVERS OVER 2" #8 OVER 10-7/8" #57 STONE	S.F.	9,270	$14.40	$133,488.00	$6.70	$62,109.00
25 PERVIOUS PAVERS OVER 2" #8 OVER 3" #57 OVER 17" #2 STONE	S.F.	5,660	$16.05	$90,843.00	$8.70	$49,242.00
26 PERVIOUS PAVERS OVER 1" #8 OVER 4" #57 STONE	S.F.	1,184	$14.00	$16,576.00	$7.00	$8,288.00
27 8.5" PERVIOUS CONCRETE OVER 25" #57 STONE OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	2,360	$17.15	$40,474.00	$13.25	$31,270.00
28 8.5" PERVIOUS CONCRETE OVER 25" #57 STONE SURROUNDING 9" CLASS 2 AGGREGATE BASE AND FILTER FABRIC OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	2,090	$19.00	$39,710.00	$13.30	$27,797.00
29 5" POROUS ASPHALT OVER 25" #57 STONE OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	2,270	$15.20	$34,504.00	$7.00	$15,890.00
30 5" POROUS ASPHALT OVER 25" #57 STONE SURROUNDING 9" CLASS 2 AGGREGATE BASE AND FILTER FABRIC OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	1,700	$17.00	$28,900.00	$8.50	$14,450.00
31 4" AC OVER 6" CLASS 2 AGGREGATE BASE AND 4" AC OVER 11" CLASS 2 AGGREGATE BASE	S.F.	76,655	$3.40	$260,627.00	$2.75	$210,801.25
32 VARIABLE DEPTH AC OVERLAY	TONS	31	$72.00	$2,232.00	$80.00	$2,480.00
33 GRIND EXISTING AC PAVEMENT	S.F.	720	$3.00	$2,160.00	$2.00	$1,440.00
34 SLURRY SEAL	S.F.	35,800	$0.10	$3,580.00	$0.33	$11,814.00
35 BOLLARD	EACH	260	$375.00	$97,500.00	$135.00	$35,100.00

Figure 22. Portion of Bid Abstract. (*36*)

The table below takes the numbers found in the abstract pertaining to permeable pavements and gives a sum of the costs (*36*). The item numbers match those found in the figure above for reference. The actual bid costs are also shown (complete information can be found in Appendix B).

Table 1. Permeable Pavement Total Cost.

	Estimate		ASR Constructors, Inc.	
Item #	Unit Bid	Total Bid	Unit Bid	Total Bid
23	$ 15.35	$389,890.00	$ 7.55	$191,770.00
24	$ 14.40	$133,488.00	$ 6.70	$ 62,109.00
25	$ 16.05	$ 90,843.00	$ 8.70	$ 49,242.00
26	$ 14.00	$ 16,576.00	$ 7.00	$ 8,288.00
27	$ 17.15	$ 40,474.00	$ 13.25	$ 31,270.00
28	$ 19.00	$ 39,710.00	$ 13.30	$ 27,797.00
29	$ 15.20	$ 34,504.00	$ 7.00	$ 15,899.00
30	$ 17.00	$ 28,900.00	$ 8.50	$ 14,450.00
TOTAL	**$ 128.15**	**$ 774,385.00**	**$ 72.00**	**$ 400,825.00**

After negotiations, if all the costs mentioned for the implementation of these permeable pavements are taken into consideration, while excluding those costs for pre-construction or operations and maintenance, the total cost came out to be about $400,825.00 for the facility to implement permeable pavers. Compared to the engineer's estimate of $774,385.00, the cost for permeable pavements came at a significant discount.

Cost information for operations and maintenance is also not available for each individual BMP on the site. The cost, per year, of maintaining the facility's entire LID BMP demonstration facility is $25,000.00. This includes the costs to clean and maintain the facility, as well as replace plants as needed (*7*). Over the 4 years since completion, this has been roughly $75,000 on top of the initial $2.5 million investment. This high cost would not be likely for most developments since the demonstration facility built several LIDs, more than most facilities would include. The additional BMP implementation and the larger surface area that was converted from impervious to pervious increased the cost of the implementation significantly. The maintenance cost per BMP would be advantageous for the facility to further examine.

According to the study by Orange County, LID can be worth the cost for compliance purposes, as well as in the amount of runoff reduced and made sustainable (33). If the facility further broke down the cost of the individual BMPs and their projected cost of operation and maintenance, it would give a clearer picture of how these BMPs compare to each other as it pertains to implementation.

CHAPTER THREE

EFFECTIVENESS AND FUCTIONALITY

Low Impact Development Effectiveness and Functions

This chapter seeks to give a complete assessment of the effectiveness and the control for each BMP. These components were studied to comprehensively analyze which practice best fits the needs of a development.

Effectiveness and Functions

Consideration for the effectiveness of sustaining stormwater is a vital detail when LID BMPs are to be implemented. This section identifies the advantages and disadvantages of different BMPs. A review of literature research and utilized projects assisted in the conclusions drawn about the effectiveness of bioretention, biofiltration and infiltration, and pervious pavers. Effective BMPs should assist in alleviating the effects of urban runoff into receiving waters (*37*). Controlling runoff rates, reducing pollutants by reducing runoff, removing total suspended solids, and being readily maintainable are qualities BMPs should possess in order to effectively sustain stormwater management(*37*).

Bioretention. As mentioned previously, bioretention is capable of collecting water in order to treat stormwater runoff, while also recharging groundwater and lowering the amount of surface runoff. Figure 23 below shows an illustrated cross-section of a bioretention basin and its construction.

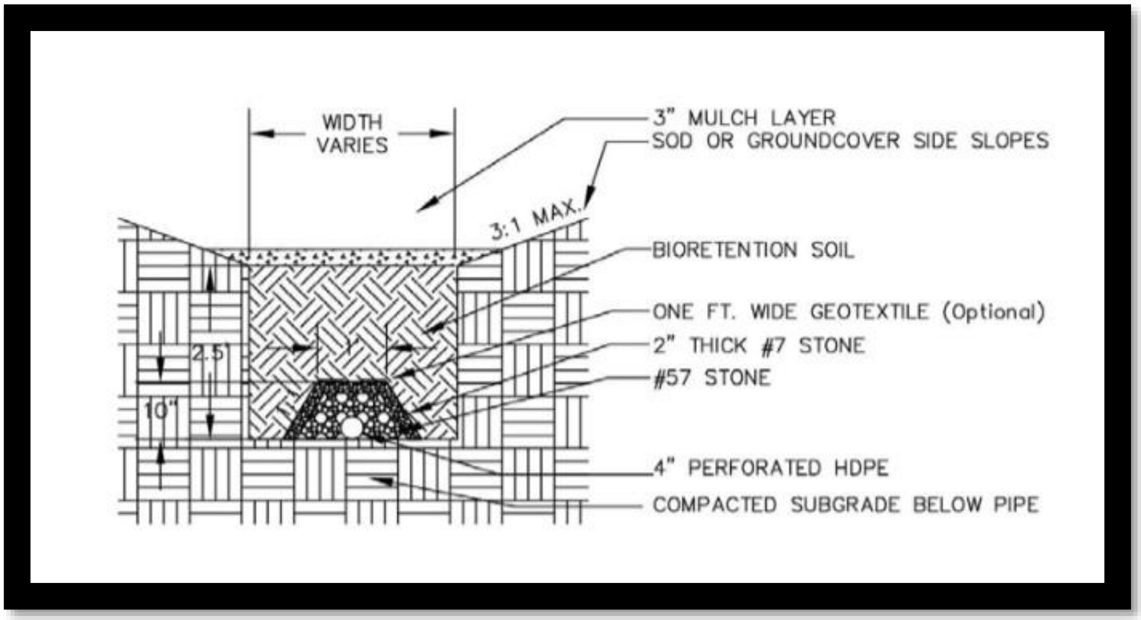


Figure 23. Cross-section of a Bioretention Cell. (*18*)

The advantages of a bioretention cell include high removal of certain pollutants that may be of specific concern to an area's water quality. Metals (specifically copper, lead, and zinc) show a high retention rate when infiltrated through a bioretention cell. Dependent on soil content, design, and media composition, bioretention cells have shown to be very efficient at removing pollutants from stormwater runoff (*6*). The same has been seen for conventional constituents, such as total suspended solids and total petroleum hydrocarbons. The removal of these pollutants has shown to be significant and it would be effective to employ this BMP to manage their stormwater. Another advantage is the functionality of bioretention cell BMPs during cold weather. During frozen conditions, infiltration through bioretention cells has been shown to be similar to its normal functionality (*38*). Even though frost may form in the soil, the cells have shown to still infiltrate runoff while frost is present. Figure 24 shows another example of a bioretention cell.

Figure 24. Bioretention BMP. (*18*)

Disadvantages of bioretention systems are similar to common limitations seen in other best management practices. First, they have a low removal rate for nitrate and total phosphorus. The variations in studies of nitrogen seizure by bioretention cells are evident in many studies. One study in North Carolina, through further monitoring of the cell, demonstrated a noteworthy removal of ammonia and Kehldahl nitrogen (ammonia/ammonium plus organic nitrogen). Due to the likely influx of groundwater into the system, there were increases in the nitrate-nitrogen. There was some evidence of nitrate-nitrogen being introduced that did not appear high in the influent (*6*). The problem with a lack of removal in phosphorus is commonly seen due to the engineered soil used in the filtration system. An alternative medium should be considered if it demonstrates high levels of phosphorus during examination, in order to reduce the export of phosphorus into the effluent (*4*). Since nitrate is a negatively charged ion, this causes the soil particles to reject it rather than clutching onto it like they would with other pollutants, like metals. A plausible reaction for the low removal rate of nitrate-nitrogen explored in other studies is the creation of nitrate-nitrogen between storm events, through mineralization and nitrification from nitrifying bacteria as well as other sources of nitrogen (*4*). Figure 25 shows an example of a bioretention cell at the CalTrans district headquarters in San Diego, California.

Figure 25. Bioretention BMP. (*18*)

One proposed solution involves lifting the underdrain buried in the cell; by lifting it higher, more water is able to inundate the area, which would eventually allow for the reduction of the nitrates into nitrogen gas and release them into the atmosphere. It has also been shown that some areas, specifically where the water has a harder time infiltrating the soil, may need an underdrain installed. This would add another installation cost to the development project.

The performance of a bioretention cell has, overall, had optimistic results. Bioretention cells have proven to lower both runoff volumes and velocities, in addition to most pollutants from stormwater runoff, despite the export of phosphorus and low reduction of nitrogen (*4*). The efficiency of bioretention cells at lowering stormwater runoff demonstrates promise. The management of water quality also shows efficiency as it pertains to significant pollutants. A study done by Brown, et al. in 2012 showed that several LID BMP sites were examined for water quality and it was found that bioretention cells had the ability to reduce runoff in several cases at a rate ranging from 45% to 87%. In one case, a bioretention cell reduced up to 98% of runoff (*28*).

<u>Biofiltration and Infiltration Practices</u>. Biofiltration systems, are employed to collect stormwater and use the natural microbes in the system to absorb pollutants. Infiltration basins, on the other hand, collect stormwater and work specifically to recharge groundwater. Figure 26 shows an illustrated cross-section of a completed biofiltration swale.

Figure 26. Cross-section of a Biofiltration Swale. (*39*)

Although each system is implemented for slightly different tasks, they all have a lot of the same advantages and disadvantages. One great advantage is the recharge of groundwater. Their ability to allow water to percolate through the soil and recharge groundwater is the main reason many permits require a type of infiltration BMP to be implemented (*41*). Bioinfiltration has the added advantage of removing pollutants because these systems contain vegetation and microbes that can absorb or decompose the pollutants naturally as the water permeates through the soil. Their highest successes have shown to be in removing total suspended solids and metals. Nutrients have shown to have a much lower removal rate; however, the quantities removed are significantly higher than other

BMPs. This difference can be attributed to the plants and microbes present in bioswales, which consume and produce nutrients naturally.

The disadvantage these two BMPs share is the over-retention of water. If water does not infiltrate quickly enough, the basin, or swale, can become a stagnant pond and mosquito breeding ground. The rates of infiltration are dependent on both the texture of the soil media and the structure of the basin (*41*). If the infiltration rate is not high enough, this could pose an issue for downstream water bodies that may rely on the groundwater that the basin is helping to recharge. To counteract this, the systems need to be maintained so that the stormwater runoff can percolate into the soil within 72 hours, like they are designed to do.

Infiltration basins have a disadvantage because the basins themselves have not been proven to remove pollutants. It can be assumed that the soil in the basin removes pollutants because of the lack of data showing otherwise; however, it cannot be proven that it is not some other factor that is removing the pollutants.

Swales have the disadvantage that they can only be employed for small drainage areas, due to their slow percolation process. In the study by Brown, et al., biofiltration BMPs examined at several different sites indicated a runoff reduction of 11% to 33% (*28*). Figure 27 shows an illustration of a cross-section for an infiltration basin BMP.

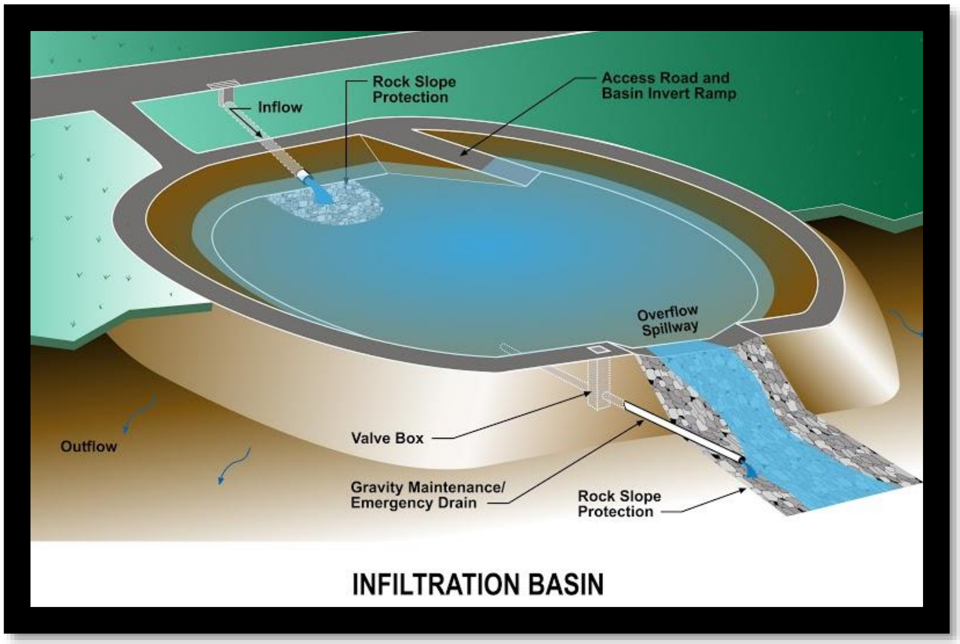


Figure 27. Illustration of an Infiltration Basin. (*40*)

Permeable Pavements. Permeable pavements have one specific goal to fulfill- reduce the impermeable surface area of traditional paved surfaces. By achieving this, the amount of stormwater runoff is greatly reduced and the amount of groundwater recharge and pollutant control is increased. Different types of permeable pavers include: porous concrete, grid concrete blocks, pervious interlocking blocks, pervious asphalt, and plastic block pavers. Pavers have the demonstrated ability to efficiently reduce urban runoff when designed, implemented, and maintained adequately (*28*). Permeable pavements can be found as concrete blocks, pervious asphalt, and pervious concrete. Due to the capabilities of permeable pavers to treat the quality and reduce the quantity of the runoff, these BMPs can effectively alleviate the impacts on stormwater that new developments and redevelopments create. Even though permeable asphalts and concretes share the same goal, the differences of each type still present their own advantages and disadvantages. For the purpose of this section, a general view of their efficiencies and functions will be established. Figure 28 shows an illustration of a cross-section for a pervious pavement BMP.

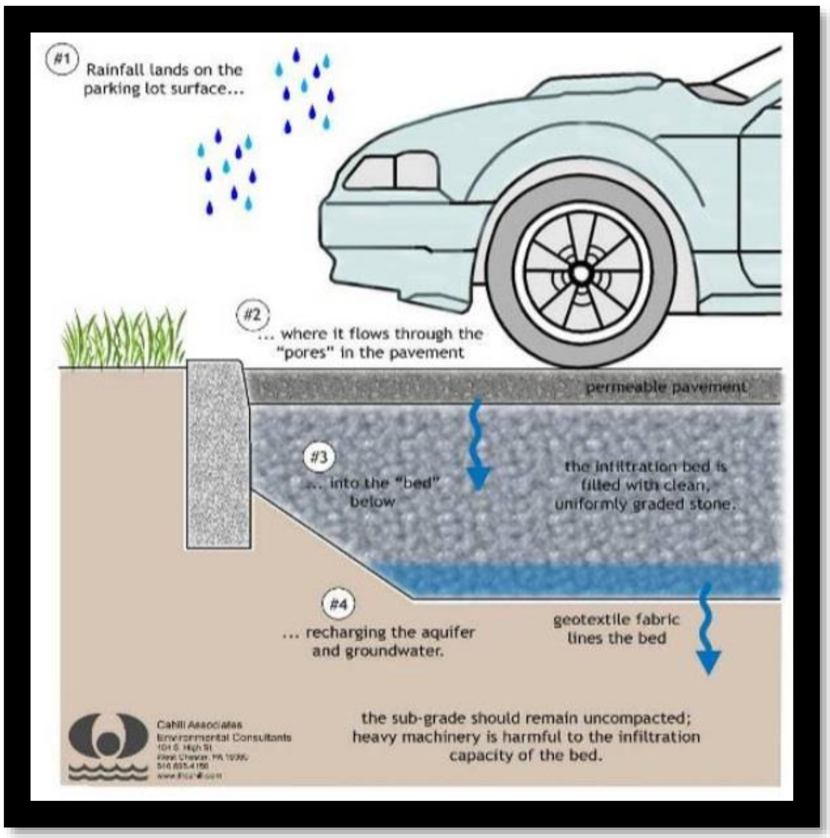


Figure 28. Cross-section for Permeable Pavements. (*18*)

Permeable pavements have many advantages, ranging from pollutant removal to a long expected lifespan. They have shown to be outstanding at removing pollutants. Metals, including copper, lead, and zinc, have shown a high reduction with these BMPs. Studies have shown that total suspended solids and nitrogen have both been successfully removed through permeable pavements. Nitrogen's high removal rate was also seen in the case study. With some maintenance, cold weather has little effect on the performance of permeable pavements. Furthermore, permeable pavements have shown that they will not create ice in cold weather, due to their rapid infiltration rates for runoff.

The most significant result found in studies of permeable pavements is the performance of this BMP during winter months. One study showed that infiltration functionality did not diminish during the winter months (like it was expected to do) since the pore space is large enough to allow for drainage even during frost and freezing (*29*). Runoff from streets and walkways in a storm event is most important. One of the goals of LID is to aid in flood control through the reduction of runoff and peak flows. In the study by Brown, et al., it was seen that pavement reduced runoff at the highest volume compared to other BMPs. Their ability to reduce runoff ranged from 25% to almost 90%, with most of the sites showing reduction above 80% for porous pavements (*28*). Pavements have a very high ability to reduce stormwater runoff, but they are also able to better control the temperature of the runoff during warm weather. Traditional asphalt is generally responsible for much of the extra heat in cities, while concrete is lighter in color and absorbs less heat. This advantage reduces heat from the island heat effect that is seen from traditional asphalts. Similarly, in the winter months, porous asphalt will be warmer and will assist in the deicing of roads. During the nighttime, less lighting will be required due to the light color of the pavements, which will help reflect more light compared to traditional black pavements (*29*). The durability of permeable pavements ranges from 12 to 15 years in cool environments and up to 30 years in warm environments; which is similar to traditional non-porous asphalt surfaces. Most importantly, pavement systems pose no threat of pollutants to the groundwater they recharge (*4*). The lifetime of the system is related to the maintenance provided. In order for it to live its expected lifetime, it requires a great deal of maintenance, including washing, cleaning, and replacement of soil after time. Figure 29 shows an established porous concrete BMP.

Figure 29. Porous Concrete BMP. (*18*)

The potential for contamination is low in residential areas, due to the fact that the pollutants regularly found in stormwater have a high affinity to soil. Even though the system could become clogged, the amount of infiltration it undergoes is still significant (especially when compared to traditional pavements). Research of pavement BMPs on the East Coast has shown that permeable pavers, such as pervious pavements or concrete grid and blocks, can still effectively infiltrate large amounts of stormwater runoff, despite potential clogging by increased loading of fine particles onto the surface. After replacement of the clogged media, the infiltration rate of the pavers will increase even more (*4*). Figure 30 shows decrease in runoff allowed by the infiltration abilities of the greater porosity of permeable asphalt.

Figure 30. Permeable Asphalts. (*18*)

There are some disadvantages to installing permeable pavements. Although pervious concrete has a high removal for nitrogen, other types of pavements have shown little removal of this pollutant. The same limitation is seen with phosphorus; however, this is a common limitation for permeable pavements. Systems have been observed to release more nitrate and phosphate than the system received. Microorganisms and chloride do not seem to have any reduction through these systems. In the studies by Dietz, the soil does not filter out bacterial indicators from the runoff collected. One proposed solution to this problem is to design the systems similarly to a bioretention cell. The proposed design would be to install a denser reservoir of course additives (*4*), then underlie the system to increase the amount of runoff collected and increase the percolation times.

Another limitation seen is that the system has a high chance of becoming clogged if the proper maintenance is not employed. In order to improve the clogging issues on permeable pavements, it was found that vacuuming, washing with high pressure, and removal of sludge through suction was the most effective way to clean the system (*4*). This maintenance does not adversely affect the pavement's infiltration abilities. However, this particulate problem can be solved by routine cleaning of the asphalt and the maintenance routine mostly depends on the frequency of use that the system is subjected to.

Other clogging issues present include both the particulates introduced from the surface and particles that can mix with a type of binder that are known to permanently clog a system. The binder and particle mix can be addressed by adequately selecting a binder for the pavement system. In the study of Roseen's paper by Gunderson in 2008, it was demonstrated that even with 99% clogging in the system, the pavements could still infiltrate over ten inches of runoff per hour (*29*). This potential to continue infiltration, even in light of clogging, is a definite advantage for implementing permeable pavements.

Case Studies: Effectiveness and Function

In this section, the effectiveness and functionality data of LID BMP implementation is fully examined. An assessment of the effectiveness of the implementation and water quality observed so far for multiple LID BMPs will convey a wide-ranging impression for comparison. The data for both case studies is limited to exposure of these LID BMPs. What has been collected will not be used to set trends or to evaluate capacity, but rather to attempt a further understanding of the advantages and disadvantages of LID BMPs (*36*).

The Facility

The facility completed implementation of its LID BMP program in 2012. After implementation, five storm events were sampled for water quality. The pervious pavements, which consist of a parking lot control for comparison, are broken down as follows: porous concrete with and without a filter, as well as pervious asphalt with and without a filter. They also incorporated a biofiltration mechanism for a planter box, with the control water collected from the rooftop.

Lastly, the facility has an infiltration basin that collects both runoff and stormwater, which is used for water quality monitoring. The basin uses the parking lot as a control for runoff reduction, while influent and effluent are both monitored and compared to each other. Generally, infiltration basins aid the management system in recharging groundwater, but due to the design of their LID BMP program, the basin also collects runoff for water quality testing. The water collected and used for sampling of water quality is then sent into the infiltration basin.

The five storms were not sufficient enough to build a trend analysis; the information gathered is subject to change after all variables of the storm events have been analyzed by the facility staff. Aside of the small sampling set the information gathered was also limited due to a drought experienced by the region where the Facility is located. This led to fewer storm events and longer intervals between events which makes trend analysis difficult. This analysis serves as a coarse impression to the advantages and disadvantages of BMPs. Appendix B has the entire worksheets that were used to extract the information shown in Table 2 through Table 7 (*36*). Constituents, or data points, not tested or not detected in three or more events were removed to give a better average of the removal percentage. The percentage represents the removal of a constituent compared to its corresponding control. The permeable pavements were compared to the impervious parking lot controls and both were designed to collect stormwater for the purposes of water quality testing. For comparison of removal, the influent and effluent runoffs from the infiltration basin were analyzed. Lastly, the biofiltration planter box was compared to the rooftop control, designed to collect rainfall for testing and comparison purposes (*36*).

Pollutant Removal

The following tables (and corresponding photographs) show a rough representation of the removal of constituents from the facility's multiple BMPs. The complete data can be found in Appendix B.

Table 2. Porous Concrete BMP With a Filter.

Porous Concrete with Filter	
Constituent	Average Percent Removal
Oil and Grease	**29%**
Hardness	-193%
Nitrate	-121%
Total Dissolved Solids	-116%
Total Suspended Solids	-108%
Total Organic Carbon	-8%
Dissolved Organic Carbon	-17%
Ammonia as N	**75%**
Total Kjehldahl Nitrogen	**36%**
Orthophosphate	**4%**
Total Phosphorus	-4%
Arsenic	-1116%
Cadmium	-77%
Total Chromium	-198%
Copper	**13%**
Iron	-465%
Lead	-108%
Manganese	-209%
Nickel	**15%**
Zinc	**69%**
Dissolved Arsenic	-1611%
Dissolved Chromium	-351%
Dissolved Copper	**7%**
Dissolved Iron	**42%**
Dissolved Lead	**65%**
Dissolved Manganese	**79%**
Dissolved Nickel	**32%**
Dissolved Zinc	**92%**

Bolded percentages indicate a reduction in the pollutant.

Table 3. Porous Concrete BMP Without a Filter.

Porous Concrete without Filter	
Constituent	Average Percent Removal
Oil and Grease	**13%**
Hardness	-182%
Nitrate	-69%
Total Dissolved Solids	-118%
Total Suspended Solids	-38%
Total Organic Carbon	-3%
Dissolved Organic Carbon	-19%
Ammonia as N	**65%**
Total Kjehldahl Nitrogen	**29%**
Orthophosphate	**24%**
Total Phosphorus	-5%
Arsenic	-714%
Cadmium	-19%
Total Chromium	-126%
Copper	-21%
Iron	-180%
Lead	-10%
Manganese	-65%
Nickel	**17%**
Zinc	**59%**
Dissolved Arsenic	-956%
Dissolved Chromium	-202%
Dissolved Copper	-37%
Dissolved Iron	**21%**
Dissolved Lead	**35%**
Dissolved Manganese	**55%**
Dissolved Nickel	**5%**
Dissolved Zinc	**82%**

Bolded percentages indicate a reduction in the pollutant.

Both concrete types, filter or not filtered, showed reduction in several constituents. Oil and grease were removed by both the concrete systems, but had a higher percent removal by a difference of 16% in the filtered concrete. Figure 31 shows the difference in runoff during a storm event at the facility. The area on the left of the photo is traditional asphalt and the area on the right (the parking stalls) is the porous concrete.

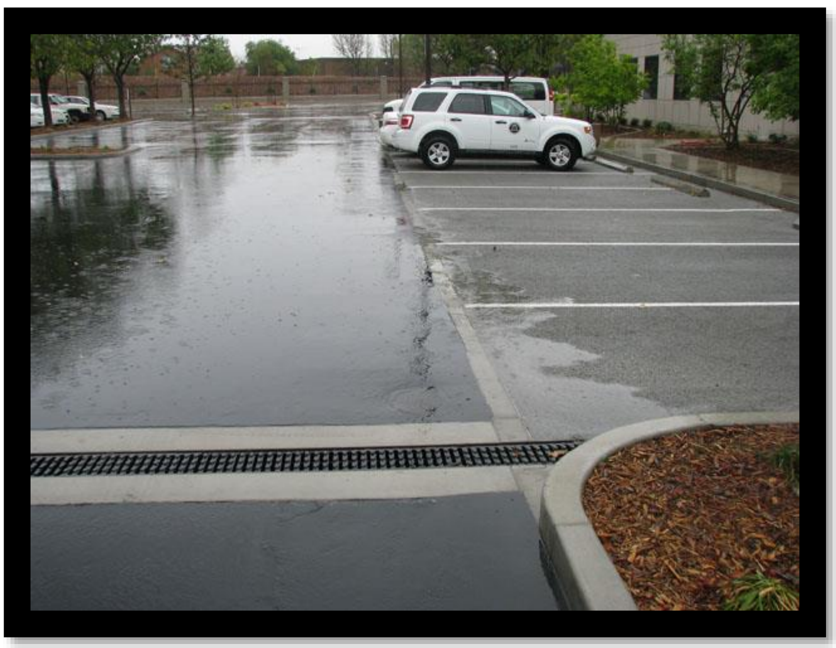


Figure 31. The Facility's Porous Concrete During a Storm. (*30*)

Nutrients, including ammonia, total Kjehldahl nitrogen, and orthophosphate, also showed a high percent reduction, but in both cases removal was highest for ammonia. Copper (total) has a higher reduction in the concrete with the filter than the concrete without. Both nickel and zinc were removed readily by the concretes. Most of the dissolved metals show reduction in both cases, with manganese and zinc showing the highest affinity for removal. This pattern of removal has been seen in other implemented LID BMPs, as shown in the study by Brown in 2012. Total dissolved solids, metals, and nutrients are readily removed by the LID BMP (*28*).

It is also be seen in both table 2 and table 3 (above), that there constituents that showed a negative reduction. This negative removal indicates an increase in the concentration instead of the expected reduction. For example, in the February 2014 sampling event, hardness increased yielding a -271% removal which contributed to the average percent removal reported in table 2 (above) of -193%. The actual value increased from 14mg/L to 38mg/L, while this is in fact an increase, the increase is expected since the water passing through concrete would pick up calcium, magnesium, and other minerals from the concrete that would contribute to hardness.

There are several possible reasons that may contribute to a constituent increase, one example of these reasons was mentioned earlier, the storm events sampled were months apart. Regular rain events would allow for regular "washing" of the entire facility therefore the buildup of constituents over time could be adjusted for, which is not possible in this case due to the lack of regular storm events. Other possible reasons will be discussed later.

Table 4. Pervious Asphalt BMP With a Filter.

Pervious Asphalt with Filter	
Constituent	Average Percent Removal
Oil and Grease	-20%
Hardness	-278%
Nitrate	-199%
Total Dissolved Solids	-111%
Total Suspended Solids	-1%
Total Organic Carbon	-34%
Dissolved Organic Carbon	-56%
Ammonia as N	**74%**
Total Kjehldahl Nitrogen	**30%**
Orthophosphate	**34%**
Total Phosphorus	**29%**
Arsenic	-404%
Cadmium	-47%
Total Chromium	-32%
Copper	-165%
Iron	-334%
Lead	-9%
Manganese	-129%
Nickel	-59%
Zinc	**65%**
Dissolved Arsenic	-567%
Dissolved Chromium	-6%
Dissolved Copper	-224%
Dissolved Iron	**40%**
Dissolved Lead	**76%**
Dissolved Manganese	**32%**
Dissolved Nickel	-60%
Dissolved Zinc	**70%**

Bolded percentages indicate a reduction in the pollutant.

Table 5. Pervious Asphalt BMP Without a Filter.

Pervious Asphalt without Filter	
Constituent	Average Percent Removal
Oil and Grease	**9%**
Hardness	-219%
Nitrate	-165%
Total Dissolved Solids	-98%
Total Suspended Solids	**26%**
Total Organic Carbon	-56%
Dissolved Organic Carbon	-78%
Ammonia as N	**80%**
Total Kjehldahl Nitrogen	**23%**
Orthophosphate	**63%**
Total Phosphorus	**48%**
Arsenic	-176%
Cadmium	-125%
Total Chromium	**2%**
Copper	-267%
Iron	-152%
Lead	**41%**
Manganese	-72%
Nickel	-165%
Zinc	**61%**
Dissolved Arsenic	-256%
Dissolved Chromium	**33%**
Dissolved Copper	-373%
Dissolved Iron	**26%**
Dissolved Lead	**73%**
Dissolved Manganese	**14%**
Dissolved Nickel	-167%
Dissolved Zinc	**56%**

Bolded percentages indicate a reduction in the pollutant.

The asphalts, which are found in the parking lot area, also had similar successes in pollutant removal with or without the filter. The greatest difference was that oil and grease had a positive percent removal in the case of the asphalt without the filter. Oil and grease are introduced through vehicle traffic, and then washed away through runoff. This causes an overexposure to the pollutant and is harder to remove from the runoff. Figure 32 below shows another location at the facility's parking lot, demonstrating the difference between the porous asphalt and traditional asphalt. The traditional asphalt is located on both sides of the photo (with the cars parked on top of them), while the porous asphalt is located in the middle.

Figure 32. The Facility's Pervious Asphalt Parking Lot. (*30*)

Total suspended solids also have higher success of removal with the unfiltered asphalt. This correlates with the pattern seen in the reduction of total metals by the pervious asphalts. The unfiltered asphalt had a higher percent removal of pollutants than its filtered counterpart. Like what was seen earlier, there were also metals and other constituents that increased in concentration. Also, like before, most of these increases can be explained due to how small the actual values are. For this BMP the concentration units for the metals measured in micrograms per liter (a thousand times smaller than the milligram units earlier) so an increase from 1 – 5µg/L, corresponds to an increase of 500% but the specific values are miniscule since the microgram is a millionth (10^{-6}) of a gram, or thousandths of a milligram. These increases can be attributed to several potential causes which will discussed in more detail later.

From the constituents that showed reduction, ammonia and dissolved lead were removed in the largest quantity by the unfiltered and filtered asphalt, respectively. These nutrients, as shown in other studies, have a high removal rate by this type of practice (*28*). The complete data can be found in Appendix B.

Table 6. Infiltration Basin BMP.

Infiltration Basin	
Constituent	Average Percent Removal
Oil and Grease	**55%**
Hardness	-122%
Nitrate	-53%
Total Dissolved Solids	-158%
Total Suspended Solids	-39%
Total Organic Carbon	-33%
Dissolved Organic Carbon	-40%
Ammonia as N	-65%
Total Kjehldahl Nitrogen	-35%
Total Nitrogen	-14%
Orthophosphate	-521%
Total Phosphorus	-321%
Arsenic	-73%
Total Chromium	-32%
Copper	-29%
Iron	-12%
Lead	**21%**
Manganese	-44%
Nickel	-32%
Zinc	**10%**
Dissolved Copper	-69%
Dissolved Iron	-45%
Dissolved Nickel	-58%
Dissolved Zinc	-12%

Bolded percentages indicate a reduction in the pollutant.

Table 7. Infiltration Basin BMP.

Biofiltration Planter	
Constituent	Average Percent Removal
Oil and Grease	**1%**
Hardness	-428%
Nitrate	-165%
Total Dissolved Solids	-468%
Total Suspended Solids	-17%
Total Organic Carbon	-42%
Dissolved Organic Carbon	-52%
Ammonia as N	**76%**
Total Kjehldahl Nitrogen	**15%**
Total Nitrogen	-65%
Orthophosphate	-51%
Total Phosphorus	-46%
Arsenic	-410%
Total Chromium	-75%
Copper	-39%
Iron	-89%
Lead	-34%
Manganese	-25%
Nickel	-104%
Zinc	**73%**
Dissolved Arsenic	-423%
Dissolved Chromium	-106%
Dissolved Copper	-38%
Dissolved Iron	-77%
Dissolved Nickel	-114%
Dissolved Zinc	**81%**

Bolded percentages indicate a reduction in the pollutant.

From the facility's BMP data provided for this case study, the infiltration basin (shown below in figure 33) and the biofiltration planter box (shown below in figure 34) had the least success in the removal of pollutants. As stated earlier, both BMPs have strength in recharging groundwater and not much has been studied in their ability to reduce runoff or pollutants (*22*). This could explain the low number of pollutants removed by these types of BMPs. Compared to the pavements, the planter box and the infiltration basin removed the least amount of pollutants over the five storms. Unlike the pavements however, the infiltration basin actually had a high percent removal of oil and grease. This is a significant accomplishment since, as shown in figure 33 below, the basin is adjacent to a parking lot; and the primary source of oil and grease is vehicles.

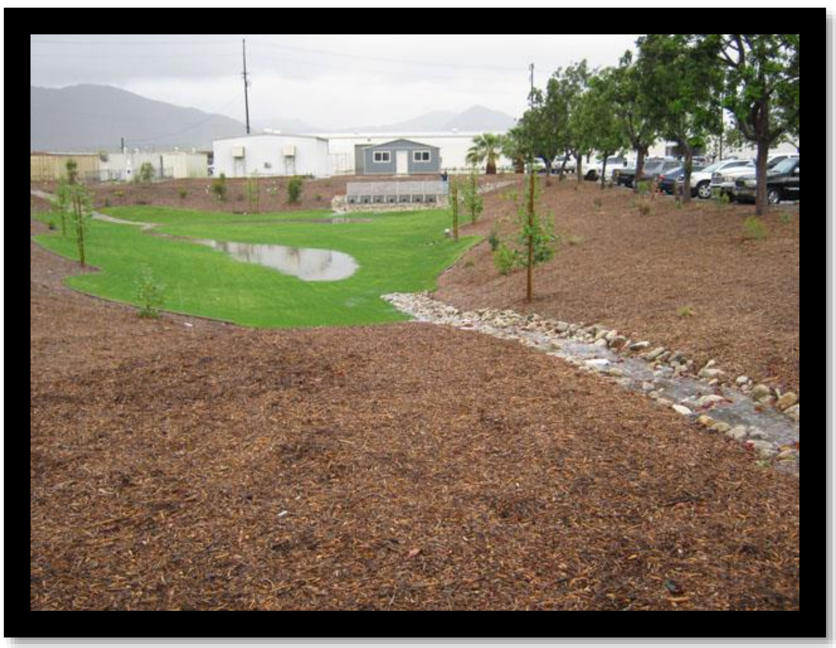


Figure 33. Infiltration Basin at the Facility After a Storm. (*30*)

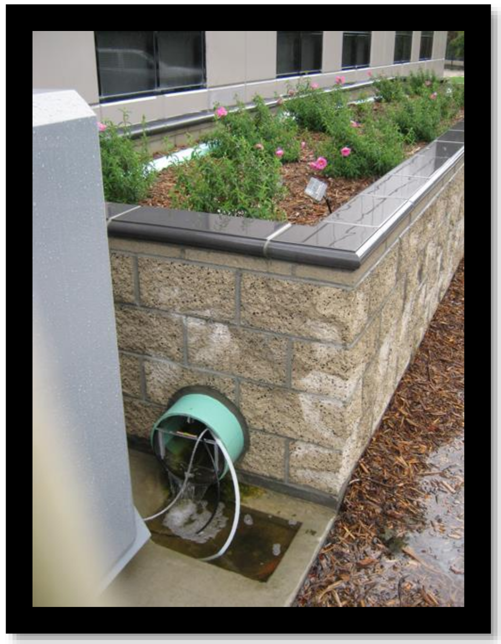


Figure 34. Planter Box After a Storm. (*30*)

The only nutrients to show reduction in the planter box BMPs were ammonia and total Kjehldahl nitrogen. These patterns are also evident in other studies, where nutrients have a successful removal through biofiltration (*4*). The metals, generally, did not show a successful percent reduction. As discussed with the porous asphalts earlier, the actual values for all the metals were measured in micrograms per Liter, also referred to as parts per billion (ppb).

Arsenic is probably the most alarming increases. As reported in table 8 (above) the percent removal of arsenic is -410%, meaning aresnic actually increased in concentration, however like the others mentioned earlier the specific increases are minor. For example, during the storm event from January 2013 the concentration of Arsenic on the pavement used as a control was estimated at

0.4µg/L, the concentration increased to 2.4µg/L; This corresponds to a percent removal of -600% however the actual increase was only about 2µg/L. For comparison purposes the United States Environmental Protection Agency has set the standard for arsenic at 10 ppb in drinking water (*46*). This standard is four times greater than the 2.4 ppb that arsenic concentration increased to, further illustrating the very low concentrations that were found. This increase could be caused by small amounts of arsenic, and other metals, being washed into the basin and planter box during small rain events, sprinklers, etc and then getting retained in the BMP until the next large rain event when there is enough rain to sufficiently wash the metals into the runoff.

Runoff Reduction

Another parameter examined amount by this development is the reduction of stormwater these LID BMPs exhibit. The following table shows the BMPs side by side with a percent removal of runoff. The percentage represents the amount of water expected from the storm, after gaging a rain event, compared to the amount captured (or withheld) by the corresponding LID BMP. The complete data set can be found in Appendix B.

Table 8. The Facility's BMPs Percent Runoff Reduction.

Runoff Reduction						
BMP Type	**Mar 2012**	**Apr 2012**	**Oct 2013**	**Jan 2013**	**Feb 2014**	**Avg**
Biofiltration		88.56%	83.01%	64.82%	36.81%	68%
Infiltration	44.04%	-16.04%	53.52%	-11.08%	37.37%	22%
Porous Concrete without Filter	18.35%	-10.09%	51.50%	-78.82%	4.66%	-3%
Porous Concrete with Filter	27.37%	70.85%	-60.93%	62.16%	53.41%	31%
Pervious Asphalt with Filter	22.83%	14.79%	25.22%	24.53%	28.34%	23%
Pervious Asphalt without Filter	-8.44%	3.69%	31.26%	53.54%	-51.49%	6%

Unlike with the reduction of pollutants, biofiltration showed the greatest ability to reduce runoff, when compared to the other LID BMPs at this facility. The unfiltered pavements both showed a very low ability to reduce the stormwater flow, where the concrete had a gain in runoff by 3% (*36*).

Summary for the Facility

Overall, the pervious concrete indicates a higher removal for pollutants. It is observed that nutrients, containing nitrogen, are better removed by all BMPs in the demonstration facility. Phosphorus removal was witnessed only in the asphalt with a filter, where it showed exports in the other BMPs. As mentioned previously, this is a common occurrence, due to the soil mix exporting the nutrient into the filtrate. In the study by Dietz et al., this is a common problem seen in LID BMPs, and can be fixed through the addition of an underdrain (*4*).

There are many parameters that need to be fully examined, and many more rain events that need to be sampled before any major conclusions can be drawn regarding the effectiveness of these multiple BMPs. Compared to other studies, the removal of metals, nutrients, and oil and grease showed similar results to the overall trends seen in other studies (*4*) (*28*). While there were some contaminates, the metals specifically, whose concentration increased, these can be explained by the lack of rain events seen at the Facility. Dry weather conditions assist in the deposition of pollutants on a site by carrying contaminants through the air. Since there were so few rain events over the period the data was collected, the periods of dry weather may have built up large amounts of contaminants, over the many months between rain events; since there was no rain to wash the pollutants away repeatedly these contaminants built up until a sufficiently large rain event provided enough rain to wash the contaminants through these BMPs. The larger pore space in the porous concrete and asphalt allows for the contaminated dust to settle deeper into the concrete which can shield it from wind. This allows for the concentration of the contaminant to increase even more because it cannot be carried away with the wind and longer dry periods increased the amount the contaminant is built up over time. Another factor to potentially increase metal contamination is the proximity of the Facility to a major state highway. The facility is located adjacent to a major trucking route many of which could have carried metal contaminants from their point of origin or kicked up contamination from the roadbed that was carried by the light breeze that is common for the area. Normally, pollutants build up during dry weather and are then washed away by runoff; coincidently, the first rain event of a season contains a high amount of pollutants. With continued rain throughout the season these contaminants would likely be removed, and their concentrations decrease. Since the Facility's data was collected months apart the data is essentially the first rain event of the season every time it rains. Therefore, the storm events that have been sampled will generally contain higher contaminant loads and cannot adequately support a conclusion of pollutant removal. Regular storm events that are sampled consecutively or consistently would provide a better comparison for these purposes.

The facility has invested $2.5 million to better sustain and manage stormwater. In order to effectively achieve the goals that the LID BMPs were implemented for, sampling additional storm events needs to be further considered. Water quality testing should be done more frequently in order to see a drop in the pollutants from one storm to the next. This case study suggests that permeable pavements have both the ability to reduce pollutants and reduce runoff at a rate similar to the other LID BMPs at the demonstration facility (*36*).

CHAPTER FOUR

CONCLUSION

Summary of LID BMPs

The main goal of a Low Impact Development design is to work as closely with the natural ecosystem as possible to manage stormwater runoff. Through case studies and literature research, an overview was given on LID BMPs, specifically on their effectiveness and costs. Water pollutants are being regulated at a more stringent level, calling for better management in the form of best management practices. Through methods, controls, or procedures, stormwater must be collected and somehow treated for pollutants and reduce runoff in order to meet the requirements as a BMP. The rainfall and stormwater captured in these processes results in better sustainability (when utilized to recharge groundwater), has a higher quality (when sent into storm drains), and reduces flow rates (in flood control systems). In general, BMPs have proven benefits, such as flood control, water conservation, protection of public health, wetlands and the protection of established ecosystems, and overall improved water quality in receiving waters. The Facility whose data was specifically used for confirmation of this proved to be only partially successful. The Facility did see a decrease is several contaminants however the data was collected months apart due to infrequent storm events because of a drought in the region. The lack of adequate data sets cannot adequately support a conclusion of pollutant removal for the facility. Water quality testing should be done more frequently in order to adequately see a drop in the pollutants from one storm to the next. This case study is able to conclude that the Facility's BMPs reduce runoff at a rate similar to the other LID BMPs at other facilities.

Summary of Cost versus Effectiveness

Aside from the regulatory considerations of LID BMPs, cost is an important concern in order for implementation to occur. The cost to apply a BMP onto a new or renewed development adds a significant financial stress on developers. This analysis showed that the biofiltration practice had a lower price compared to its counterparts. Biofiltration, however, as can be seen in figure 35 below, is the BMP that covers the least area in a development due to its water drainage properties. This BMP takes so long to infiltrate, a large area would only become a mosquito breeding pool rather than manage the stormwater and its quality. As seen through the case study, this BMP only removed a few of the pollutants measured. Infiltration basins had the same advantages in their cost savings, where the cost for size was among the lowest to implement.

Figure 35. Biofiltration BMP. (*43*)

The water quality advantage of an infiltration basin is almost non-existent since the main goal of this BMP is the recharge of ground water. The facility showed a slight advantage of an infiltration basin in removing oil and grease compared to its counterparts. Bioretention cells were seen to be very expensive, since not only do they aid in reduction and management of stormwater, they also support the efforts to make a development aesthetically pleasing and have water conservation abilities. This BMP had disadvantages that were both common, such as the export of phosphorus and the possibility of requiring an underdrain. Overall, their effectiveness in achieving LID goals was sufficient for their cost to implement.

The highest efficiency per cost for a BMP was seen in the permeable pavements. Although different in mix, concretes and asphalts both have the ability to collect and maintain stormwater. Their cost was moderate for implementation, which is seen in all case studies done by Orange County (*33*), as well as only attributing one-fifth of the total cost for the facility's implementation. Pervious pavements have advantages that outweigh the disadvantages. Their pollutant removal included total metals, total suspended solids, and nitrogen or nitrogen-based products. As discussed earlier there were some contaminants that increased in concentration rather than decrease, however because the concentrations were so low the actual increases were miniscule.

With regular maintenance and upkeep, the BMP could last from 15 to 30 years depending on the climate and has even shown to maintain performance through cold weather. While the data presented here reflects the first few rain events after completion of the BMPs the data collected shows that the Facility, had a significant value in implementing the pervious pavements. The porous surfaces reduced many pollutants and managed stormwater runoff effectively.

A study by Bedan *et al.* comparing traditional stormwater management and LID systems concluded that, compared to predevelopment conditions, a residential development that implements LID BMPs has a higher reduction of stormwater runoff than previously seen in the pre-development. After construction, mass exports of total Kjehldahl nitrogen and ammonia were significantly decreased, while the concentration of metals like lead and zinc was also reduced after construction of the LID BMPs. Concentrations of both total suspended solids and phosphorus were increased after implementation of the LID practices (*17*).

LID BMP is a case-by-case focus and should be treated as such. In an personal communication, an employee at the facility stated that LID is “only one tool for stormwater management” (7). This notion is important since sites, like corresponding regulations, have their own specific constraints and opportunities. The facility employee believes that developers should have available to them all options in regards to stormwater management in order to properly address water quality impacts (*7*). Unlike stormwater management, which is a necessity all around the world, LID BMPs are the solution for management in most places. Careful considerations of cost, effectiveness, pollutant removal, durability, and regulations should be completed well before planning for implementation can be initiated.

APPENDIX A

THE FACILITY INFORMATION AND COMPLETE EFFICIENCY ANALYSIS

The author, Graciela Rivera, received permission from the facility in riverside to conduct this research and publish its findings in 2014. An engineering technician was instructed to pass along and share any, and all, data from the Low Impact Development testing facility with the author for use in this thesis. The author was granted full support of management and permission to use the data as well as preliminary analysis (graphs, charts, etc.) that were done to supplement her other research. The author chose, on her own, to redact the facility's identifying information due to the testing facility's research being very preliminary to allow the facility the ability to continue its ongoing research independently.

The content in this appendix was provided by the facility in Riverside, California. Not all the information found in these documents was used throughout the project paper. The purpose of the paper was to give a broad overview of low impact development and best management practices, using the facility as a case study of a facility with multiple LID BMPs.

Percent Removal of Pollutants by BMP

	Concrete with Filter					
	Feb-14	**Jan-13**	**Aug-12**	**Apr-12**	**Mar-12**	**AVE**
Oil and Grease	13%	30%	44%	-44%	100%	29%
E. coli	99%	ND	-14%	ND	ND	43%
Hardness	-171%	-209%	50%	-415%	-221%	-193%
Calcium				-369%	-202%	-286%
Magnesium				*	-233%	-233%
Nitrate	*	-84%	-60%	-219%	-121%	-121%
Total Dissolved Solids	89%	-203%	19%	-317%	-169%	-116%
Total Suspended Solids	-144%	-23%	-132%	*	-132%	-108%
Total Organic Carbon	-4%	-31%	50%	-69%	13%	-8%
Dissolved Organic Carbon	-27%	-34%	48%	-73%	0%	-17%
Total Pertroleum Hydrocarbons	ND	ND		ND		ND
Nitrite	*					
Ammonia as N	86%	71%	100%	55%	64%	75%
Total Kjehldahl Nitrogen	57%	37%	38%	8%	39%	36%
Total Nitrogen	*					
Orthophosphate	18%	-27%	-68%	34%	66%	4%
Total Phosphate	9%	0%	-75%	13%	33%	-4%
Motor Oil	ND	ND	ND	ND		ND
Diesel Range Hydrocarbons	ND	ND	3%	100%		51%
Arsenic	*	-1250%	-422%	-1875%	-917%	-1116%
Cadmium	ND	78%	-220%	84%	-250%	-77%
Total Chromium	-171%	-243%	-74%	-357%	-144%	-198%
Copper	6%	-7%	35%	4%	25%	13%
Iron	-332%	-357%	-525%	-757%	-352%	-465%
Lead	-114%	-83%	-68%	-140%	-133%	-108%
Manganese	-245%	-186%	-195%	-193%	-228%	-209%
Nickel	10%	-38%	29%	50%	25%	15%
Zinc	74%	73%	63%	68%	66%	69%
Dissolved Arsenic	*	-1533%		-2100%	-1200%	-1611%
Dissolved Cadmium	ND	ND		-33%	-67%	-50%
Dissolved Chromium	*	-225%		-600%	-229%	-351%
Dissolved Copper	2%	-4%		-2%	32%	7%
Dissolved Iron	-10%	44%		58%	77%	42%
Dissolved Lead	100%	80%		10%	70%	65%

Dissolved Manganese	ND	72%		76%	89%	79%
Dissolved Nickel	29%	36%		9%	53%	32%
Dissolved Zinc	90%	100%		87%	91%	92%

	Concrete without Filter					
	Feb-14	**Jan-13**	**Aug-12**	**Apr-12**	**Mar-12**	**AVE**
Oil and Grease	100%	33%	48%	-122%	5%	13%
E. coli	0%	ND	-14%	ND	ND	-7%
Hardness	-121%	-168%	50%	-304%	-364%	-182%
Calcium				-338%	-458%	-398%
Magnesium				*	-417%	-417%
Nitrate	*	-66%	-40%	-98%	-72%	-69%
Total Dissolved Solids	84%	-255%	-7%	-206%	-208%	-118%
Total Suspended Solids	33%	31%	-186%	*	-32%	-38%
Total Organic Carbon	-14%	-7%	50%	-46%	4%	-3%
Dissolved Organic Carbon	-38%	-47%	48%	-36%	-21%	-19%
Total Pertroleum Hydrocarbons	ND	ND		ND		ND
Nitrite	*					
Ammonia as N	43%	63%	85%	100%	36%	65%
Total Kjehldahl Nitrogen	34%	35%	42%	8%	28%	29%
Total Nitrogen	*					
Orthophosphate	35%	5%	14%	0%	64%	24%
Total Phosphate	32%	33%	-138%	6%	39%	-5%
Motor Oil	ND	ND	ND	ND		
Diesel Range Hydrocarbons	ND	ND	3%	ND		3%
Arsenic	*	-900%	-422%	-1100%	-433%	-714%
Cadmium	ND	100%	-240%	88%	-25%	-19%
Total Chromium	-57%	-129%	-119%	-243%	-81%	-126%
Copper	-38%	-27%	-18%	-29%	8%	-21%
Iron	-19%	-110%	-450%	-229%	-92%	-180%
Lead	29%	17%	-54%	-40%	0%	-10%
Manganese	-9%	-43%	-162%	-62%	-48%	-65%
Nickel	0%	13%	6%	45%	20%	17%
Zinc	83%	64%	32%	51%	66%	59%
Dissolved Arsenic	*	-1200%		-1067%	-600%	-956%
Dissolved Cadmium	ND	ND		-33%	-33%	-33%
Dissolved Chromium	*	-200%		-233%	-171%	-202%
Dissolved Copper	-78%	-65%		-14%	10%	-37%

Dissolved Iron	30%	0%		-11%	64%	21%
Dissolved Lead	0%	55%		20%	65%	35%
Dissolved Manganese	ND	30%		54%	81%	55%
Dissolved Nickel	-14%	-27%		27%	33%	5%
Dissolved Zinc	88%	87%		70%	84%	82%

	Asphalt with Filter					
	Feb-14	**Jan-13**	**Aug-12**	**Apr-12**	**Mar-12**	**AVE**
Oil and Grease	-60%	-33%	52%	-78%	20%	-20%
E. coli	100%	ND	100%	ND	ND	100%
Hardness	-400%	-415%	-18%	-365%	-193%	-278%
Calcium				-275%	-156%	-215%
Magnesium				*	-279%	-279%
Nitrate	*	-268%	-46%	-304%	-179%	-199%
Total Dissolved Solids	86%	-255%	-14%	-261%	-112%	-111%
Total Suspended Solids	-11%	23%	-7%	*	-9%	-1%
Total Organic Carbon	-65%	-67%	25%	-69%	4%	-34%
Dissolved Organic Carbon	-100%	-128%	24%	-73%	-5%	-56%
Total Pertroleum Hydrocarbons	ND	ND		ND		ND
Nitrite	ND					
Ammonia as N	100%	100%	77%	14%	80%	74%
Total Kjehldahl Nitrogen	50%	37%	33%	-17%	46%	30%
Total Nitrogen	*					
Orthophosphate	47%	-35%	32%	38%	88%	34%
Total Phosphate	50%	0%	17%	19%	58%	29%
Motor Oil	ND	ND	ND	ND		ND
Diesel Range Hydrocarbons	ND	ND	3%	ND		3%
Arsenic	*	-550%	-109%	-775%	-183%	-404%
Cadmium	ND	78%	-180%	64%	-150%	-47%
Total Chromium	-14%	-14%	-43%	-100%	13%	-32%
Copper	-134%	-173%	-71%	-264%	-186%	-165%
Iron	-141%	-333%	-192%	-900%	-105%	-334%
Lead	14%	-17%	62%	-140%	33%	-9%
Manganese	-91%	-160%	-44%	-274%	-76%	-129%
Nickel	-60%	-63%	-76%	-10%	-85%	-59%
Zinc	73%	69%	73%	54%	57%	65%
Dissolved Arsenic	*	-667%		-833%	-200%	-567%
Dissolved Cadmium	ND	*		-100%	-100%	-100%

Dissolved Chromium	*	0%		-17%	0%	-6%
Dissolved Copper	-204%	-254%		-233%	-204%	-224%
Dissolved Iron	40%	45%		28%	47%	40%
Dissolved Lead	100%	65%		60%	80%	76%
Dissolved Manganese	ND	58%		38%	0%	32%
Dissolved Nickel	-114%	9%		-55%	-80%	-60%
Dissolved Zinc	79%	84%		62%	55%	70%

	Asphalt without Filter					
	Feb-14	**Jan-13**	**Aug-12**	**Apr-12**	**Mar-12**	**AVE**
Oil and Grease	0%	53%	40%	-67%	20%	9%
E. coli	99%	ND	100%	*	ND	99%
Hardness	-307%	-281%	-41%	-274%	-193%	-219%
Calcium				-213%	-156%	-184%
Magnesium				*	-279%	-279%
Nitrate	*	-163%	-56%	-262%	-179%	-165%
Total Dissolved Solids	88%	-190%	-42%	-233%	-112%	-98%
Total Suspended Solids	33%	69%	11%	*	-9%	26%
Total Organic Carbon	-90%	-82%	-46%	-69%	4%	-56%
Dissolved Organic Carbon	-133%	-147%	-43%	-64%	-5%	-78%
Total Pertroleum Hydrocarbons	ND	ND		ND		ND
Nitrite	*					ND
Ammonia as N	90%	100%	55%	77%	80%	80%
Total Kjehldahl Nitrogen	30%	42%	0%	0%	46%	23%
Total Nitrogen	*					ND
Orthophosphate	73%	57%	47%	53%	88%	63%
Total Phosphate	64%	60%	29%	31%	58%	48%
Motor Oil	ND	ND	ND	ND		ND
Diesel Range Hydrocarbons	ND	ND	3%	ND		3%
Arsenic	*	-125%	-22%	-375%	-183%	-176%
Cadmium	ND	67%	-480%	64%	-150%	-125%
Total Chromium	29%	29%	-2%	-57%	13%	2%
Copper	-291%	-309%	-194%	-355%	-186%	-267%
Iron	-16%	-90%	-133%	-414%	-105%	-152%
Lead	57%	50%	65%	0%	33%	41%
Manganese	0%	-27%	-113%	-142%	-76%	-72%
Nickel	-230%	-188%	-253%	-70%	-85%	-165%
Zinc	72%	70%	58%	46%	57%	61%

Dissolved Arsenic	*	-167%		-400%	-200%	-256%
Dissolved Cadmium	ND	*		-200%	-100%	-150%
Dissolved Chromium	ND	100%		0%	0%	33%
Dissolved Copper	-422%	-515%		-351%	-204%	-373%
Dissolved Iron	25%	54%		-22%	47%	26%
Dissolved Lead	100%	100%		10%	80%	73%
Dissolved Manganese	ND	45%		-3%	0%	14%
Dissolved Nickel	-343%	-82%		-164%	-80%	-167%
Dissolved Zinc	70%	74%		24%	55%	56%

	Infiltration Basin					
	Feb-14	**Jan-13**	**Aug-12**	**Apr-12**	**Mar-12**	**AVE**
Oil and Grease	34%	59%		71%		55%
E. coli	-173%	ND		100%		-36%
Hardness	-52%	-9%		-305%		-122%
Calcium				-283%		-283%
Magnesium				-452%		-452%
Nitrate	-47%	0%		-113%		-53%
Total Dissolved Solids	-200%	-26%		-247%		-158%
Total Suspended Solids	-18%	-150%		50%		-39%
Total Organic Carbon	-2%	23%		-120%		-33%
Dissolved Organic Carbon	-2%	18%		-136%		-40%
Total Pertroleum Hydrocarbons	22%	100%		ND		61%
Nitrite	ND					ND
Ammonia as N	-3%	41%		-233%		-65%
Total Kjehldahl Nitrogen	0%	43%		-147%		-35%
Total Nitrogen	-14%					-14%
Orthophosphate	39%	-16%		-1584%		-521%
Total Phosphate	-63%	0%		-900%		-321%
Motor Oil	ND	ND		ND		ND
Diesel Range Hydrocarbons	ND	ND		100%		100%
Arsenic	0%	-20%		-200%		-73%
Cadmium	ND	0%		-67%		-33%
Total Chromium	-29%	-13%		-55%		-32%
Copper	-23%	6%		-69%		-29%
Iron	-48%	-31%		41%		-12%
Lead	21%	0%		43%		21%
Manganese	-21%	13%		-124%		-44%

Nickel	-17%	0%		-78%		-32%
Zinc	22%	14%		-7%		10%
Dissolved Arsenic	*	17%		-225%		-104%
Dissolved Cadmium	ND	100%		-200%		-50%
Dissolved Chromium	*	20%		-140%		-60%
Dissolved Copper	-109%	10%		-107%		-69%
Dissolved Iron	-5%	-35%		-95%		-45%
Dissolved Lead	*	*		-43%		-43%
Dissolved Manganese	*	-33%		-209%		-121%
Dissolved Nickel	-67%	22%		-131%		-58%
Dissolved Zinc	68%	-120%		15%		-12%

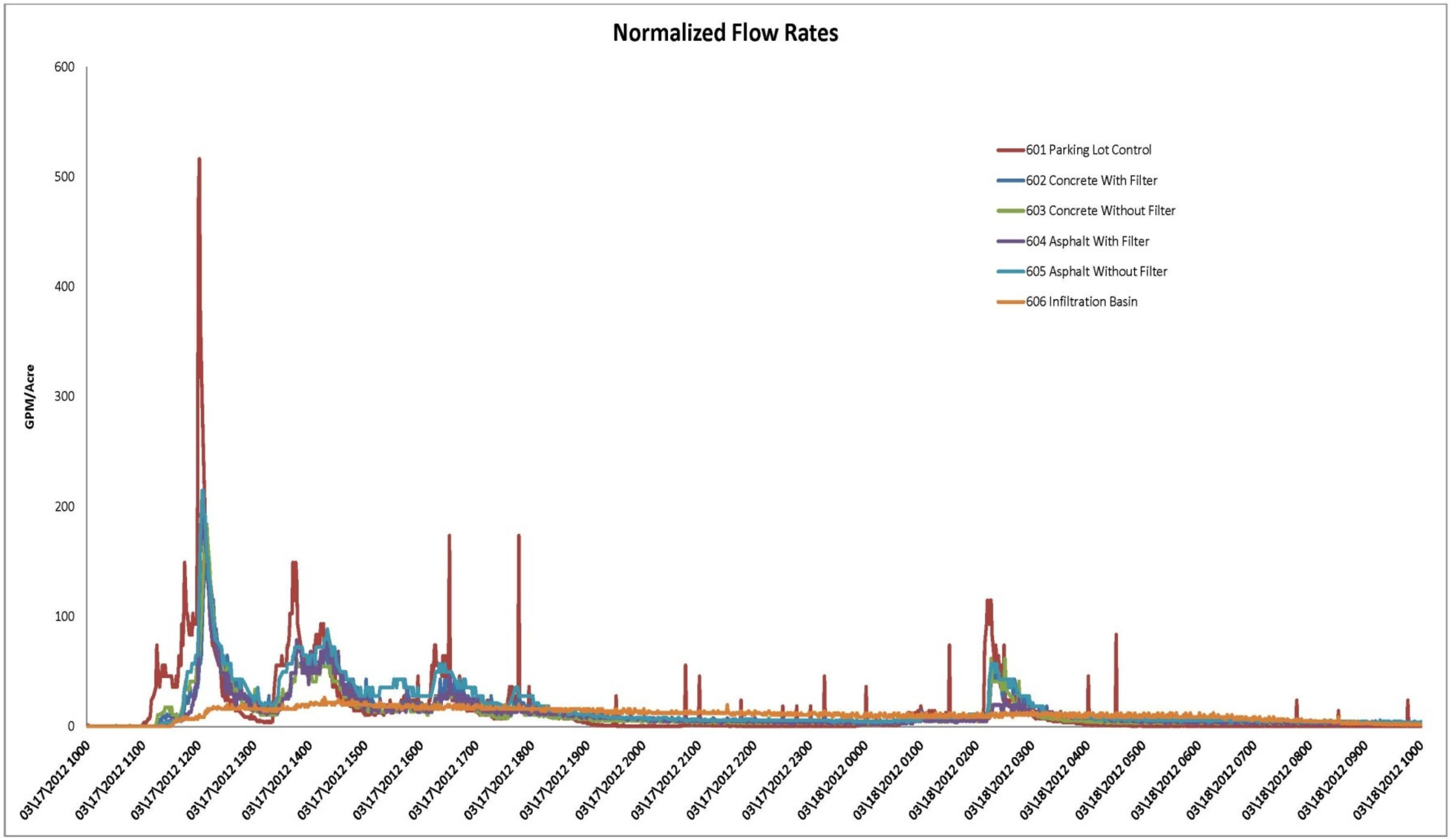
	Biofiltration Planter					
	Feb-14	**Jan-13**	**Aug-12**	**Apr-12**	**Mar-12**	**AVE**
Oil and Grease	-24%	4%		22%		1%
E. coli	75%	ND		*		75%
Hardness	-181%	-294%		-809%		-428%
Calcium				-650%		-650%
Magnesium				-1429%		-1429%
Nitrate	-297%	-103%		-97%		-165%
Total Dissolved Solids	-352%	-259%		-795%		-468%
Total Suspended Solids	-50%	-25%		25%		-17%
Total Organic Carbon	-67%	-29%		-29%		-42%
Dissolved Organic Carbon	-79%	-43%		-33%		-52%
Total Pertroleum Hydrocarbons	ND	ND		ND		ND
Nitrite	10%					10%
Ammonia as N	72%	100%		56%		76%
Total Kjehldahl Nitrogen	11%	6%		29%		15%
Total Nitrogen	-65%					-65%
Orthophosphate	11%	19%		-183%		-51%
Total Phosphate	24%	-19%		-142%		-46%
Motor Oil	ND	ND		ND		ND
Diesel Range Hydrocarbons	ND	ND		ND		ND
Arsenic	-243%	-211%		-775%		-410%
Cadmium	ND	-33%		-50%		-42%
Total Chromium	-80%	-63%		-82%		-75%
Copper	-57%	-36%		-23%		-39%
Iron	-82%	-209%		23%		-89%

Lead	-60%	-75%		33%		-34%
Manganese	-1%	-98%		24%		-25%
Nickel	-70%	-73%		-169%		-104%
Zinc	68%	72%		79%		73%
Dissolved Arsenic	-243%	-225%		-800%		-423%
Dissolved Cadmium	ND	0%		0%		0%
Dissolved Chromium	-75%	-29%		-214%		-106%
Dissolved Copper	-58%	-38%		-17%		-38%
Dissolved Iron	-228%	11%		-13%		-77%
Dissolved Lead	ND	-1150%		0%		-575%
Dissolved Manganese	ND	-174%		-24%		-99%
Dissolved Nickel	-56%	-60%		-227%		-114%
Dissolved Zinc	75%	84%		84%		81%

Percent Removal of Runoff by BMP

	Mar-12	Apr-12	Oct-13	Jan-13	Feb-14	Ave
Biofiltration		88.56%	83.01%	64.82%	36.81%	68%
Infiltration	44.04%	-16.04%	53.52%	-11.08%	37.37%	22%
Porous Concrete without Filter	18.35%	-10.09%	51.50%	-78.82%	4.66%	-3%
Porous Concrete with Filter	27.37%	70.85%	-60.93%	62.16%	53.41%	31%
Pervious Asphalt with Filter	22.83%	14.79%	25.22%	24.53%	28.34%	23%
Pervious Asphalt without Filter	-8.44%	3.69%	31.26%	53.54%	-51.49%	6%
Pavement	-0.37%	-18.84%	-67.86%	5.93%	-3.15%	-17%
Bioretention		24.02%	96.47%	3.67%	22.35%	37%

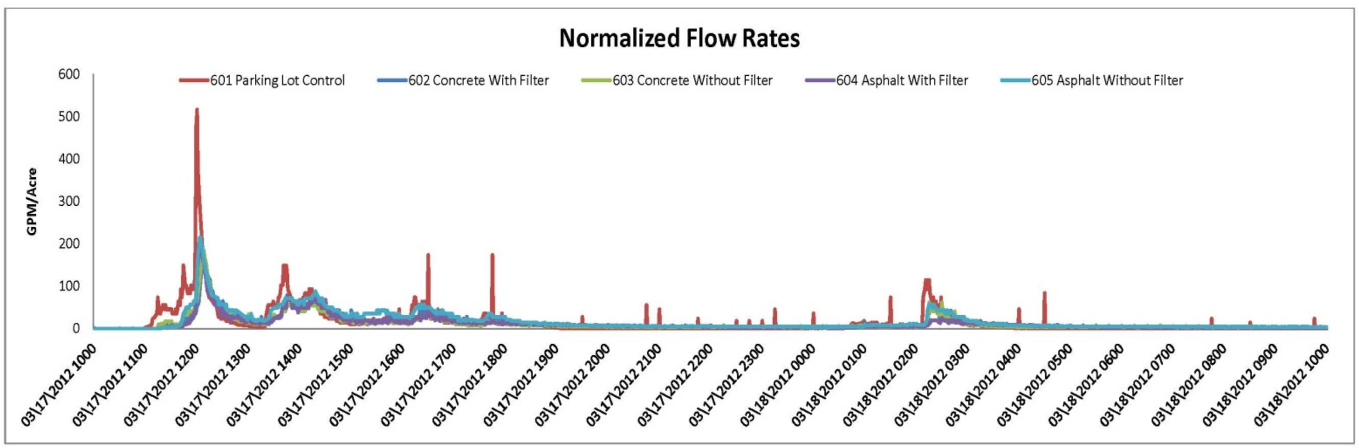
W-1 11-12 3/17/12 Sampled Event



W-1 11-12 3/17/12 Sampled Event Pavement Control vs. Pavement BMP's

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes	Flow ended (Date Time)
601	Parking lot Control	0.81	0.17	3739.143652	3752.996	-13.85234788	(-0.37%)	3/17/2012 9:42	3/17/2012 10:30	0:48	3/18/2012 4:30
602	Porous Concrete with filter	0.81	0.22	4838.891785	3951.082	887.8097851	18.35%	3/17/2012 9:42	3/17/2012 11:00	1:18	3/18/2012 3:30
603	Porous Concrete without filter	0.81	0.23	5058.841412	3674.39	1384.451412	27.37%	3/17/2012 9:42	3/17/2012 11:15	1:33	3/18/2012 4:00
604	Porous Asphalt with filter	0.81	0.16	3519.194026	2715.915	803.2790255	22.83%	3/17/2012 9:42	3/17/2012 11:20	1:38	3/18/2012 4:30
605	Porous Asphalt without filter	0.81	0.22	4838.891785	5247.295	-408.4032149	(-8.44%)	3/17/2012 9:42	3/17/2012 11:20	1:38	3/18/2012 4:00

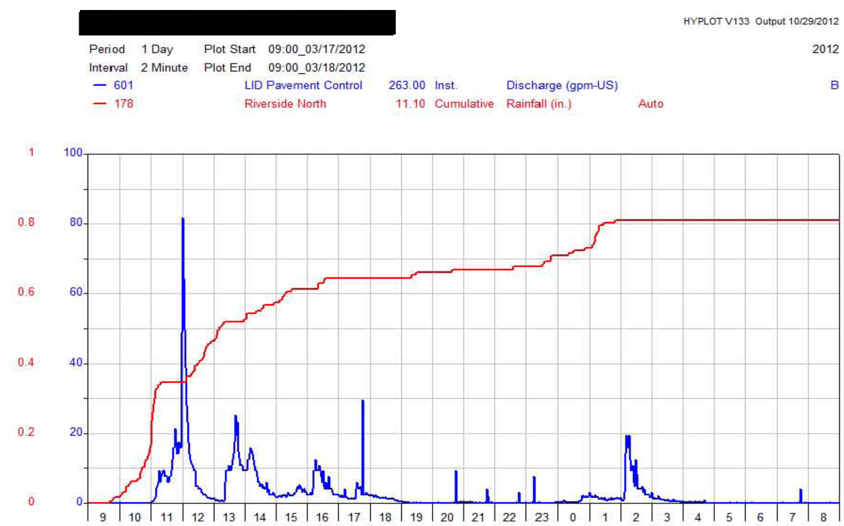
*Mathematical gains can occur when the engineered drainage area become overwhelmed and more stormwater flows into the site



W-1 11-12 3/17/12 Sampled Event -Pavement Control

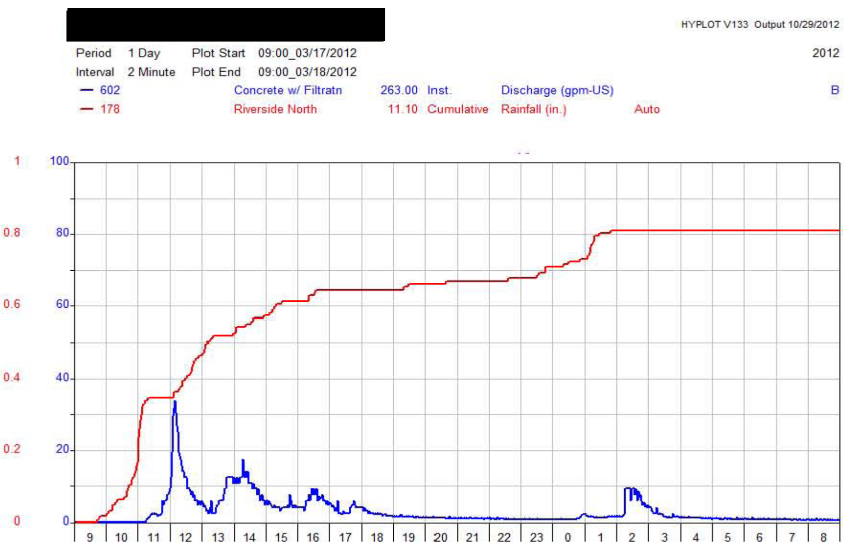
Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes)	Flow ended (Date Time)
601	Parking lot Control	0.81	0.17	3739.14	3752.99	-13.85	(-0.37%)	3/17/2012 9:42	3/17/2012 10:30	0:48	3/18/2012 4:30

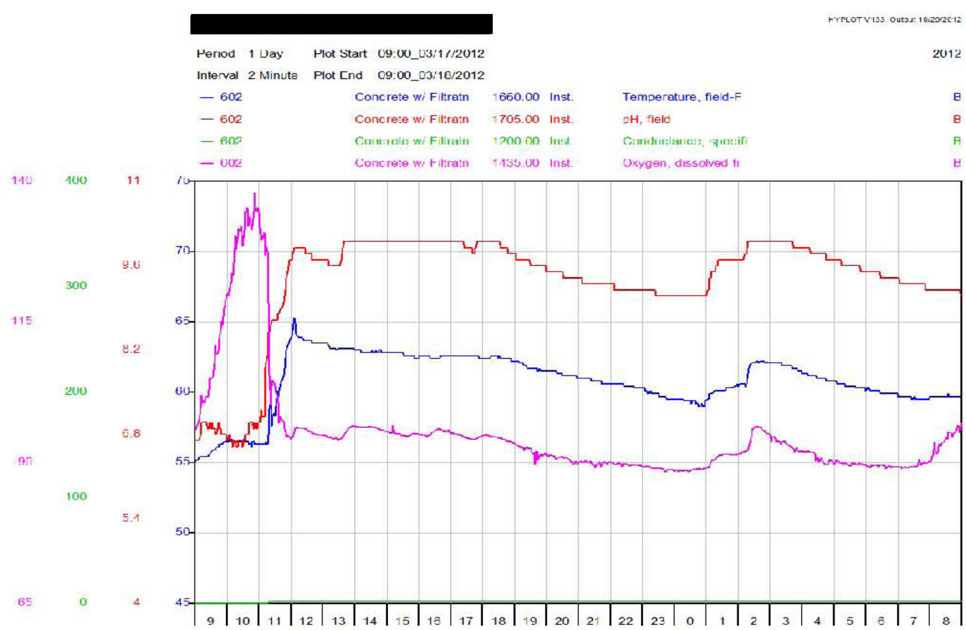
*Mathematical gains can occur when the engineered drainage area become overwhelmed and more stormwater flows into the site



W-1 11-12 3/17/12 Sampled Event –Concrete with Filter

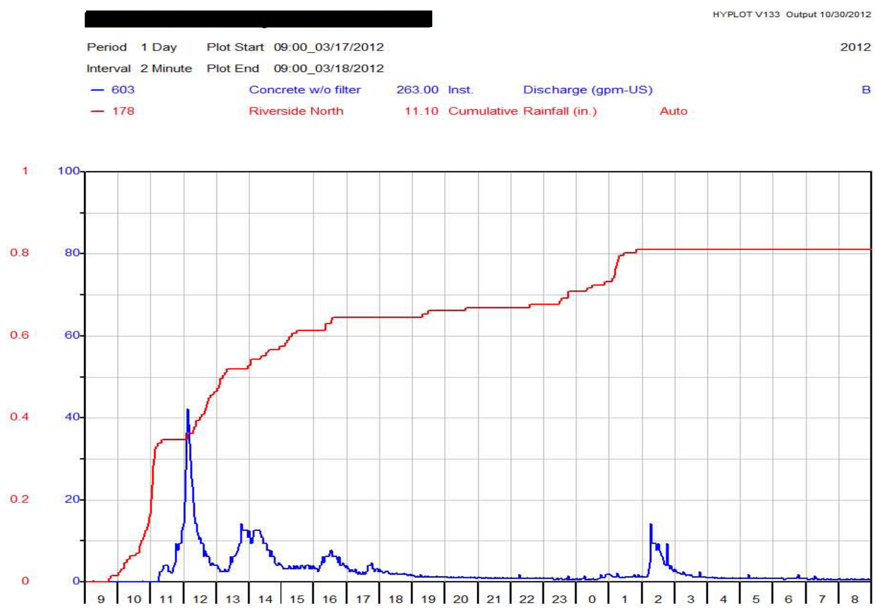
Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began -Isco (Time)	Lag Time (minutes)	Flow ended (Date Time)
602	Porous Concrete with filter	0.81	0.22	4838.89	3951.08	887.81	18.35%	3/17/2012 9:42	3/17/2012 11:00	1:18	3/18/2012 3:30

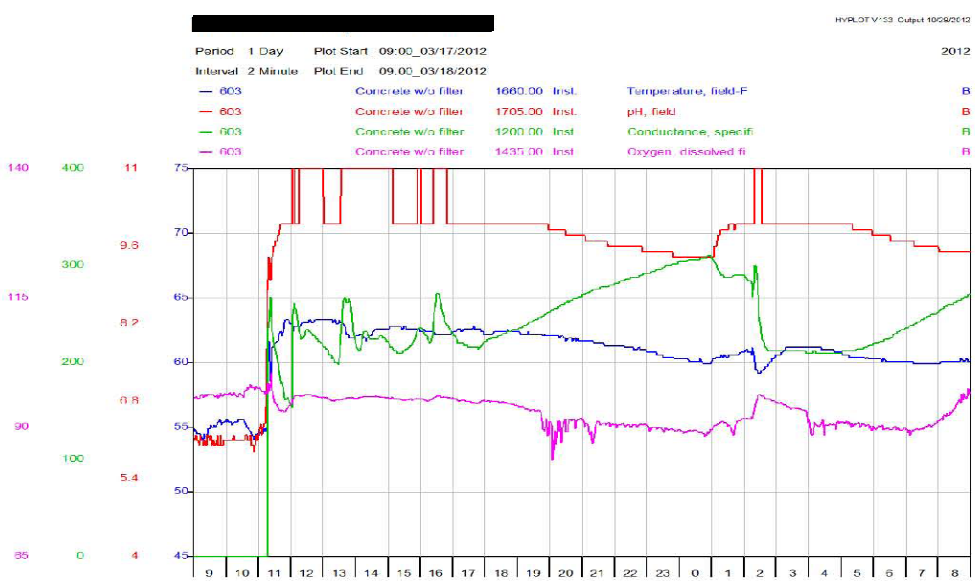




W-1 11-12 3/17/12 Sampled Event –Concrete without Filter

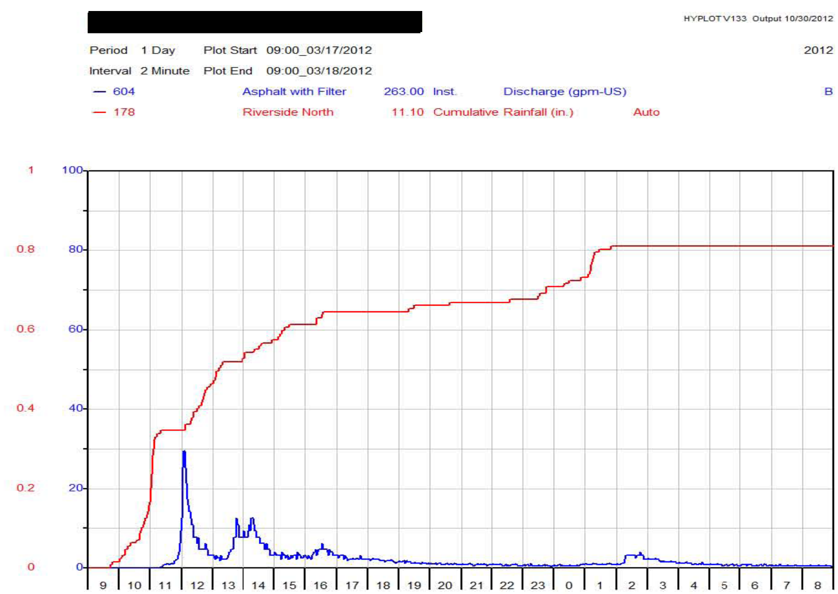
Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes	Flow ended (Date Time)
603	Porous Concrete without filter	0.81	0.23	5058.84	3674.39	1384.45	27.37%	3/17/2012 9:42	3/17/2012 11:15	1:33	3/18/2012 4:00

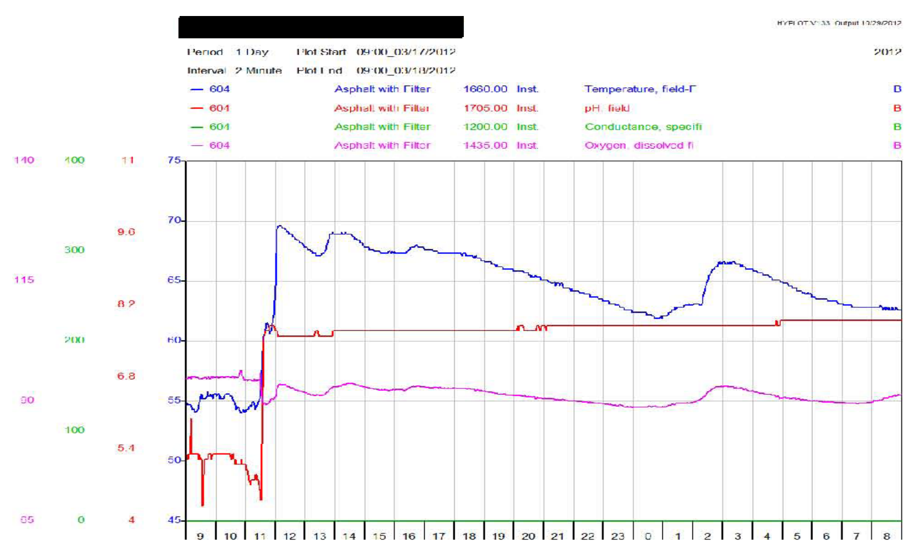




W-1 11-12 3/17/12 Sampled Event –Asphalt with Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes	Flow ended (Date Time)
604	Porous Asphalt with filter	0.81	0.16	3519.19	2715.92	803.28	22.83%	3/17/2012 9:42	3/17/2012 11:20	1:38	3/18/2012 4:30



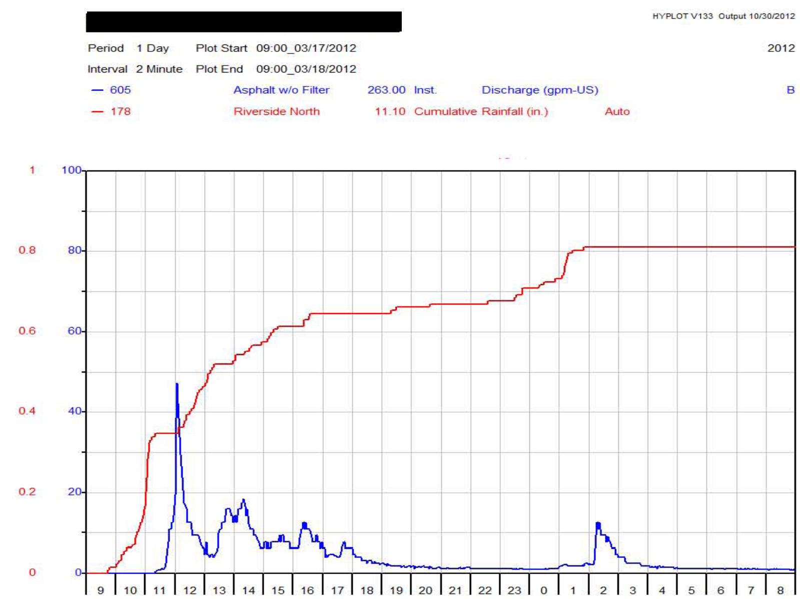


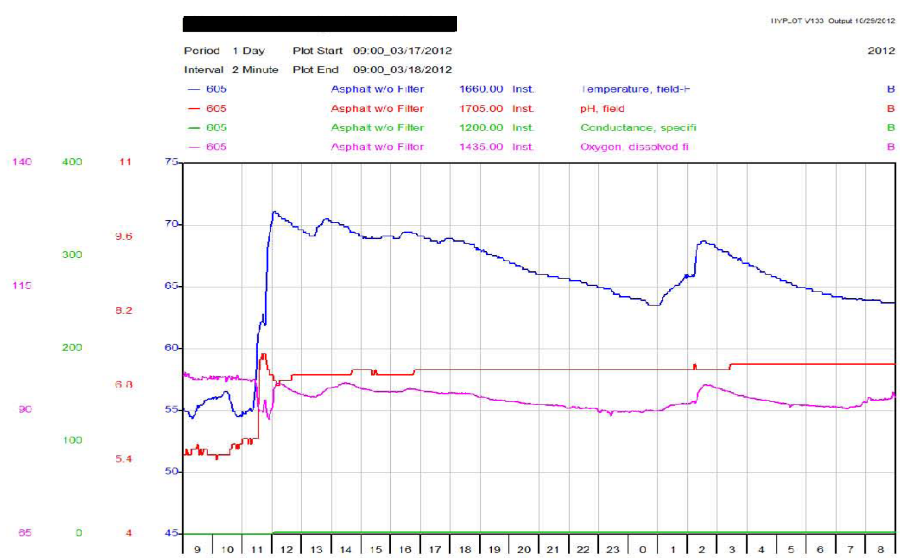
*Equipment malfunction-specific conductivity probe only recorded 0 when dry and 2 when wet

W-1 11-12 3/17/12 Sampled Event –Asphalt without Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes	Flow ended (Date Time)
605	Porous Asphalt without filter	0.81	0.22	4838.89	5247.30	-408.40	(-8.44%)	3/17/2012 9:42	3/17/2012 11:20	1:38	3/18/2012 4:00

*Mathematical gains can occur when the engineered drainage area become overwhelmed and more stormwater flows into the site

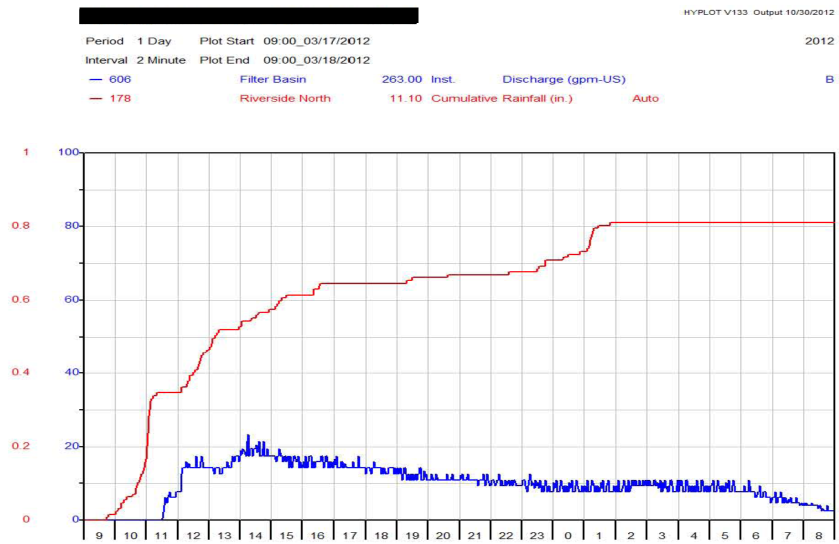


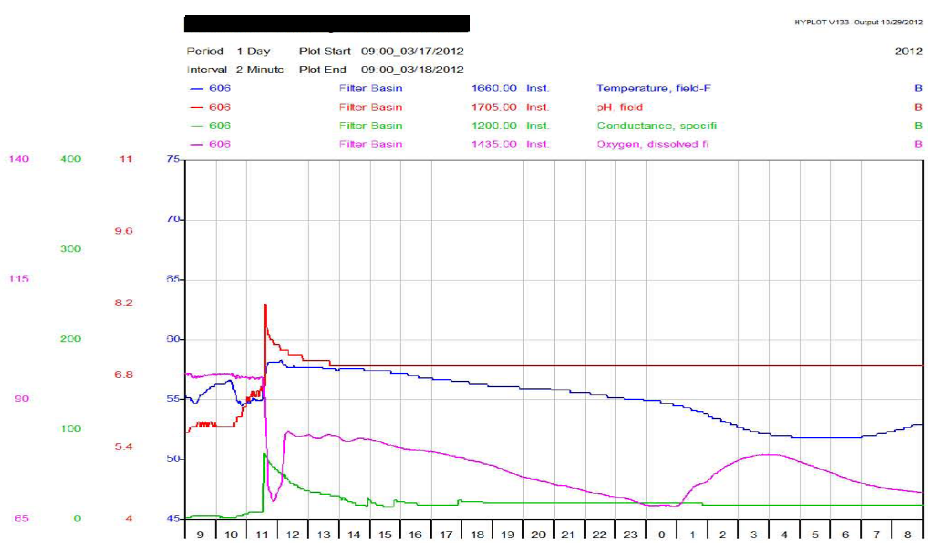


*Equipment malfunction-specific conductivity probe only recorded 0 when dry and 2 when wet

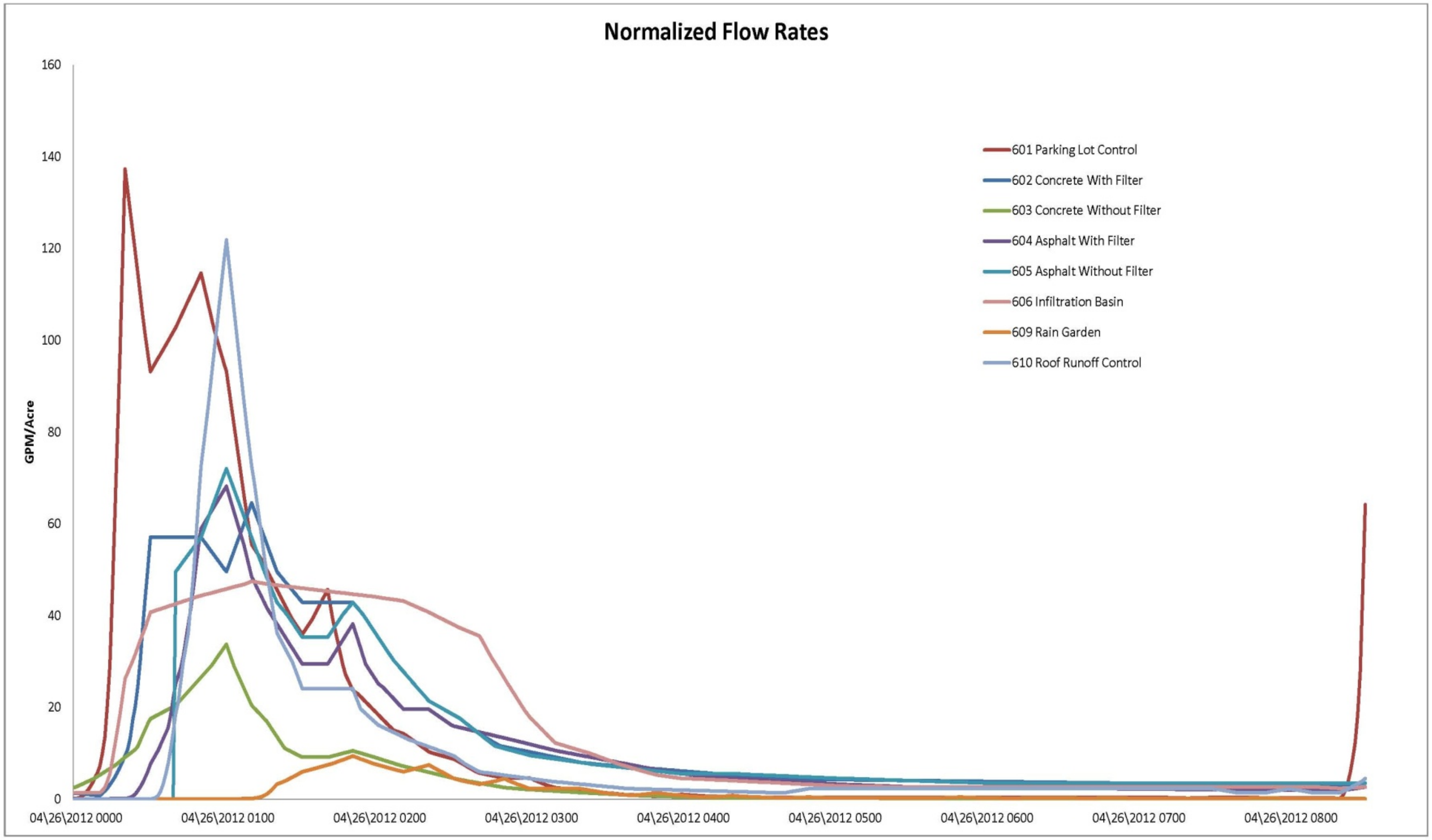
W-1 11-12 3/17/12 Sampled Event –Infiltration Basin

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes	Flow ended (Date Time)
606	Filter Basin Sub drain	0.81	0.89	19575.52	10953.81	8621.70	44.04%	3/17/2012 9:42	3/17/2012 11:30	1:48	3/18/2012 2:00





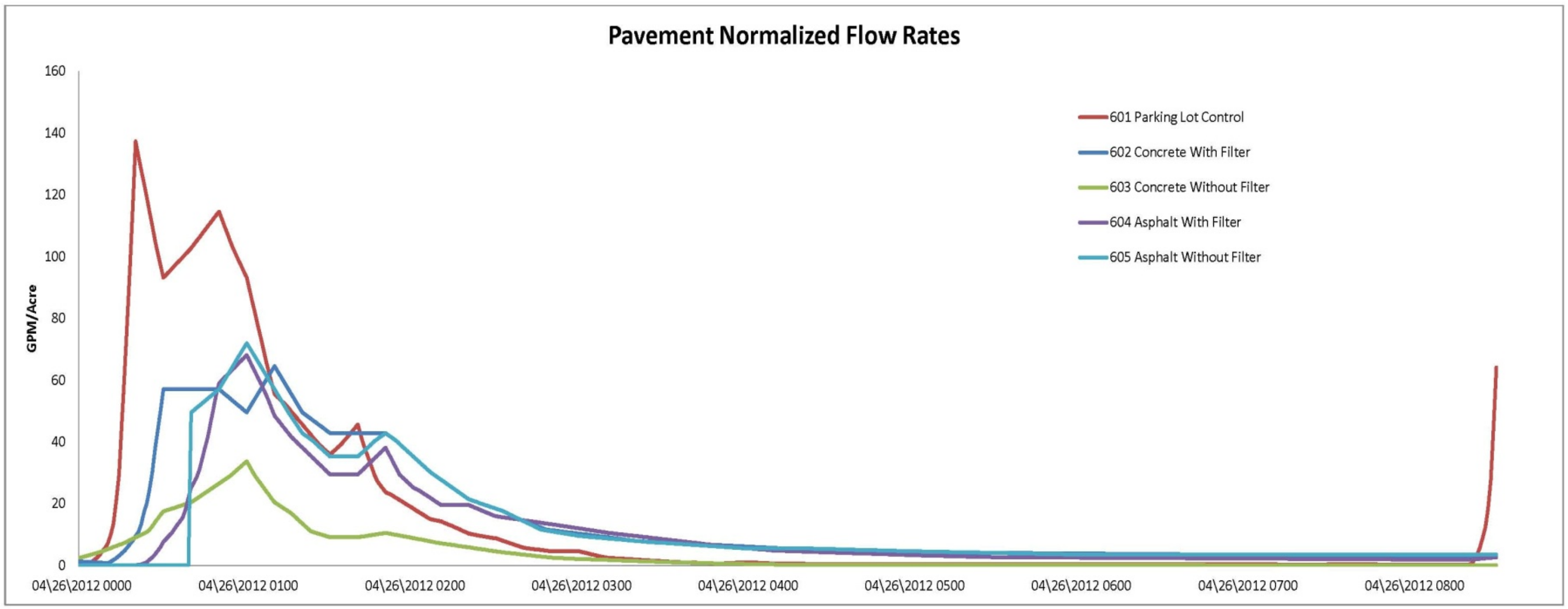
W-2 11-12 4/25/12 Sampled Event



W-2 11-12 4/25/12 Sampled Event Pavement Control vs. Pavement BMP's

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes	Flow ended (Date Time)
601	Parking lot Control	0.25	0.17	1154.06	1371.47	-217.41	-18.84%	22:51 4/25/12	4/26/2012 0:10	1:19	4/26/2012 4:50
602	Porous Concrete with filter	0.25	0.22	1493.49	1644.25	-150.76	-10.09%	22:51 4/25/12	4/26/2012 0:20	1:29	4/26/2012 8:30
603	Porous Concrete without filter	0.25	0.23	1561.37	455.19	1106.18	70.85%	22:51 4/25/12	4/26/2012 0:30	1:39	*4/26/2012 8:30
604	Porous Asphalt with filter	0.25	0.16	1086.17	925.50	160.67	14.79%	22:51 4/25/12	4/26/2012 0:10	1:19	*4/26/2012 8:30
605	Porous Asphalt without filter	0.25	0.22	1493.49	1438.40	55.09	3.69%	22:51 4/25/12	4/26/2012 0:10	1:19	*4/26/2012 8:30

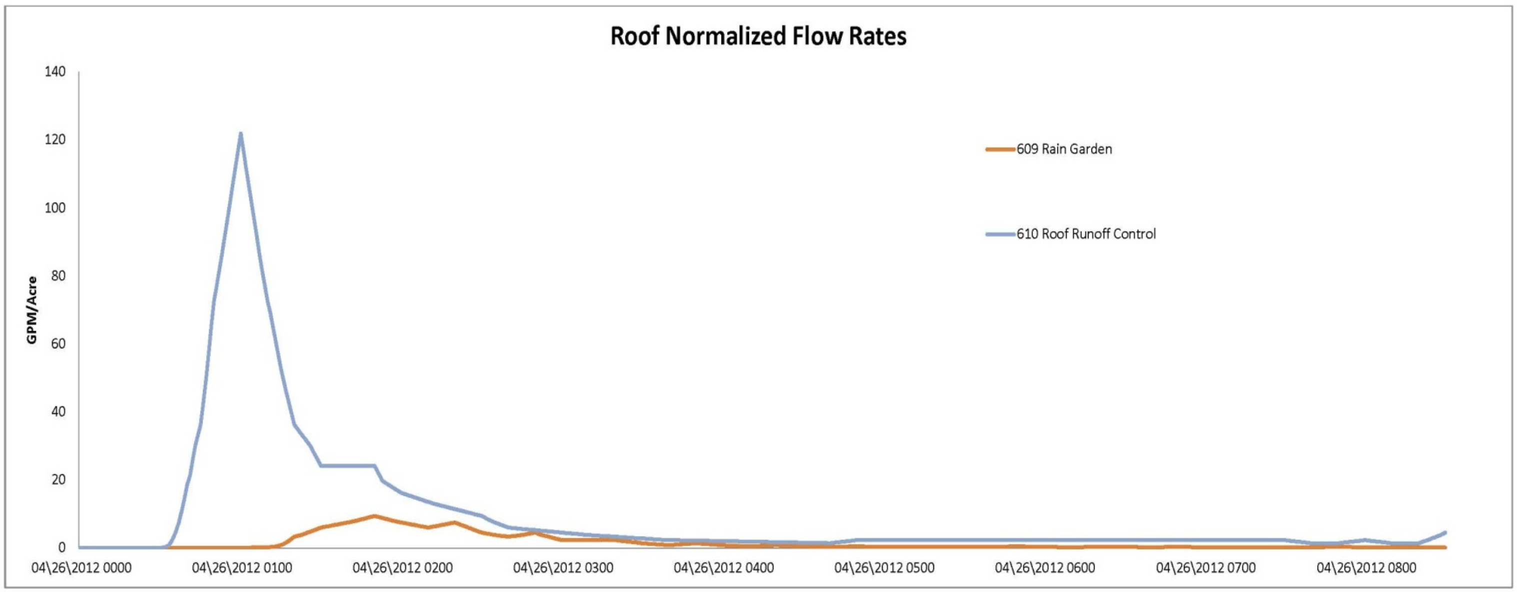
*Second rain storm from 07:22 to 08:08 on 4/26/12 0.2 inches; second band of rain began flowing through before base flow was reached



W-2 11-12 4/25/12 Sampled Event Roof Control vs. Roof BMP

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes	Flow ended (Date Time)
609	Rain Garden	0.25	0.13	882.51	100.94	781.57	88.56%	22:51 4/25/12 until 03:38 4/26/12	4/26/2012 1:10	2:19	*4/26/2012 8:30
610	Roof Runoff Control	0.25	0.13	882.51	670.55	211.96	24.02%		4/26/2012 0:40	1:49	*4/26/2012 8:30

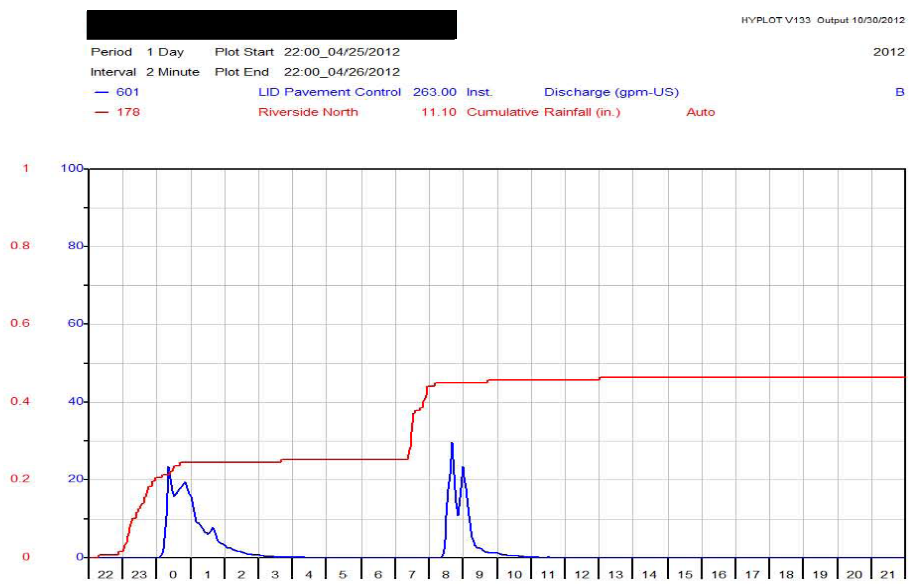
*Second rain storm from 07:22 to 08:08 on 4/26/12 0.2 inches; second band of rain began flowing through before base flow was reached

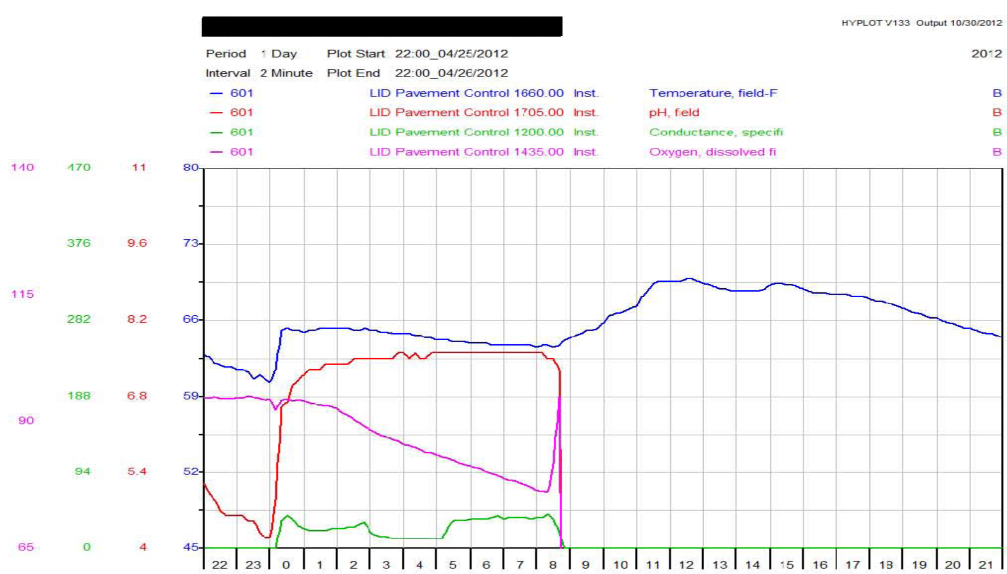


W-2 11-12 4/25/12 Sampled Event -Pavement Control

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
601	Parking lot Control	0.25	0.17	1154.06	1371.47	-217.41	(-18.84%)	22:51 4/25/12	4/26/2012 0:10	1:19	4/26/2012 4:50

*Mathematical gains can occur when the engineered drainage area become overwhelmed and more stormwater flows into the site

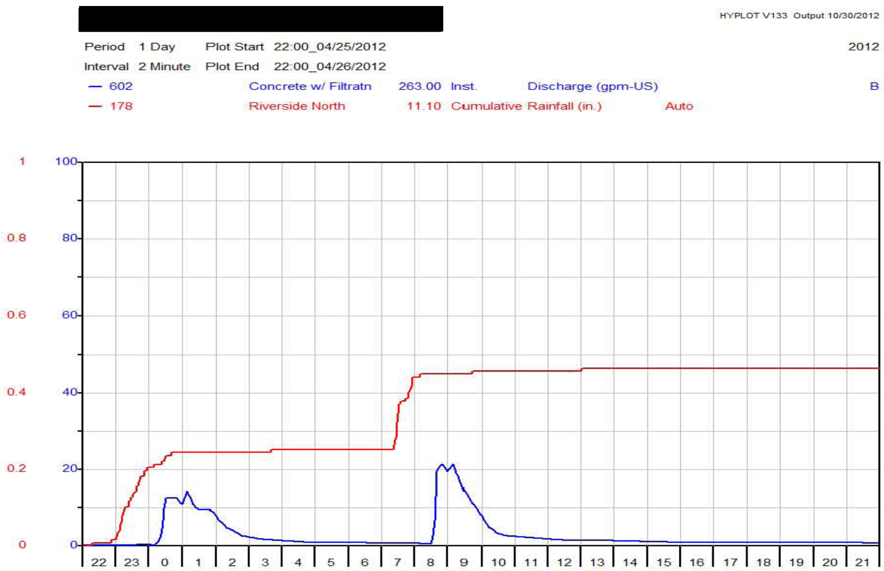


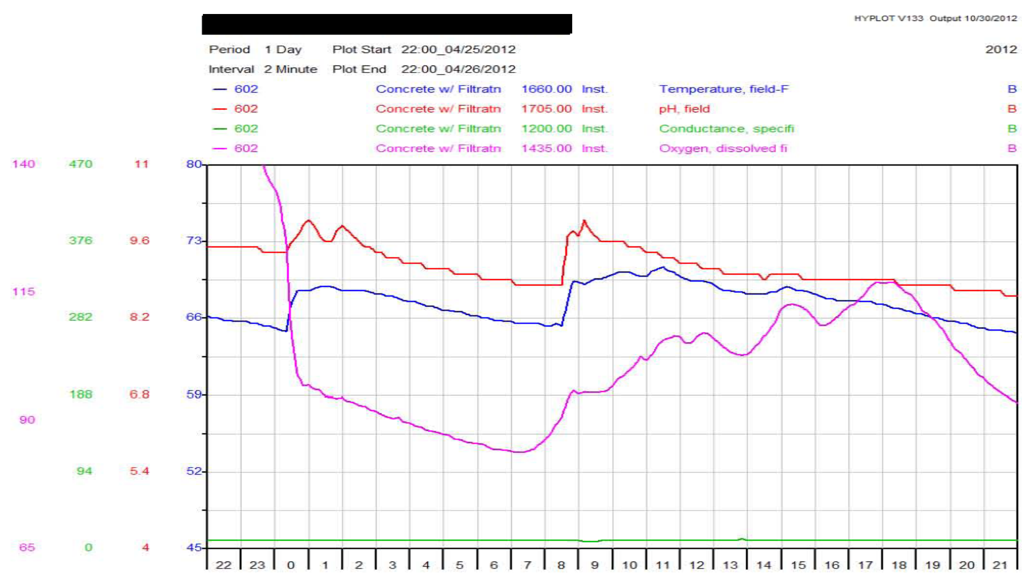


*Equipment malfunction- probes for pH, Specific Conductance, and dissolved oxygen stopped for unknown reasons

W-1 11-12 W-2 11-12 4/25/12 Sampled Event –Concrete with Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began -Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
602	Porous Concrete with filter	0.25	0.22	1493.49	1644.25	-150.76	-10.09%	22:51 4/25/12	4/26/ 2012 0:20	1:29	4/26/2012 8:30



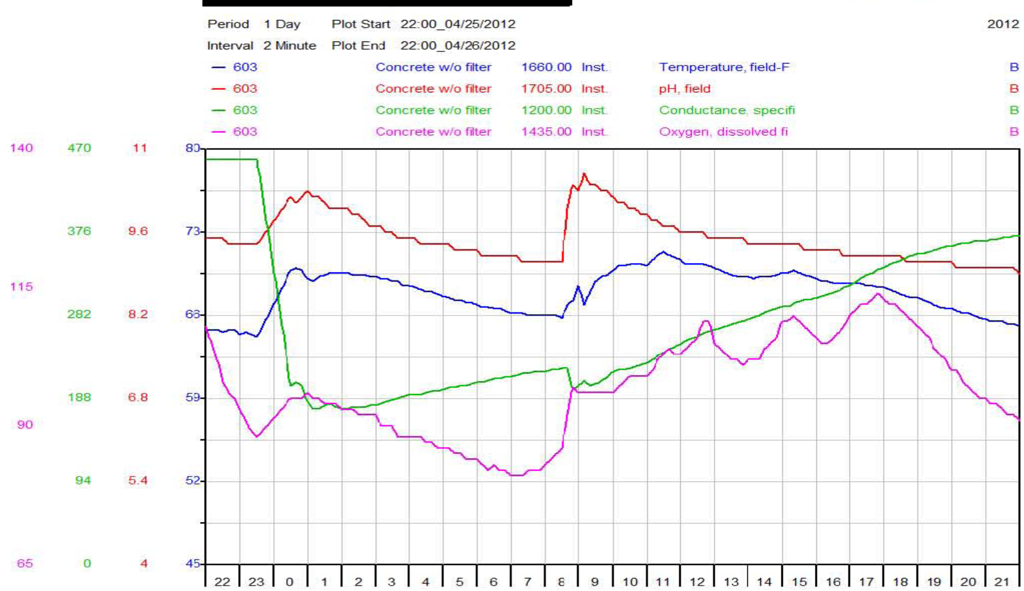


W-2 11-12 4/25/12 Sampled Event –Concrete without Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR:Min)	Flow ended (Date Time)
603	Porous Concrete without filter	0.25	0.23	1561.37	455.19	1106.18	70.85%	22:51 4/25/12	4/26/2012 0:30	1:39	*4/26/2012 8:30

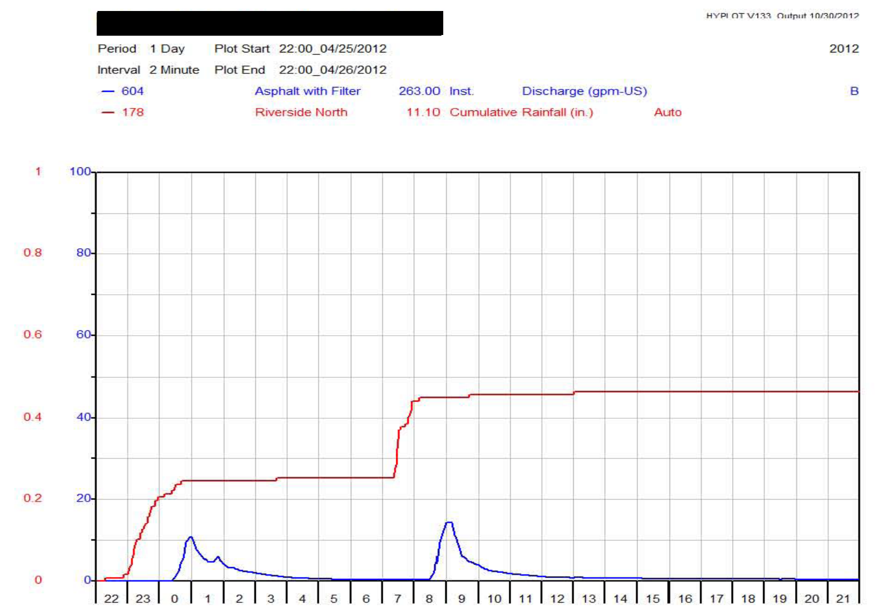
[redacted]

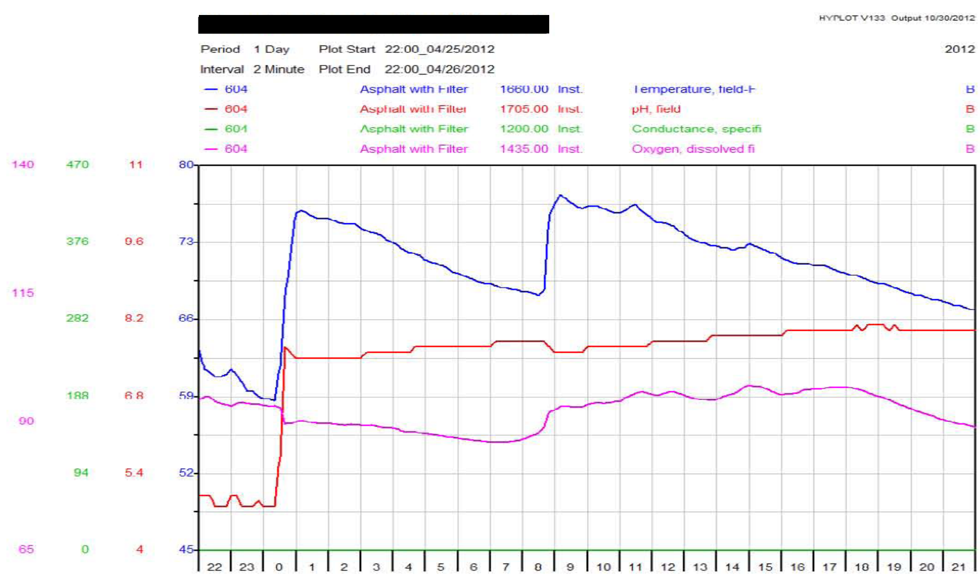
[redacted]



W-2 11-12 4/25/12 Sampled Event –Asphalt with Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR:Min)	Flow ended (Date Time)
604	Porous Asphalt with filter	0.25	0.16	1086.17	925.50	160.67	14.79%	22:51 4/25/12	4/26/2012 0:10	1:19	*4/26/2012 8:30

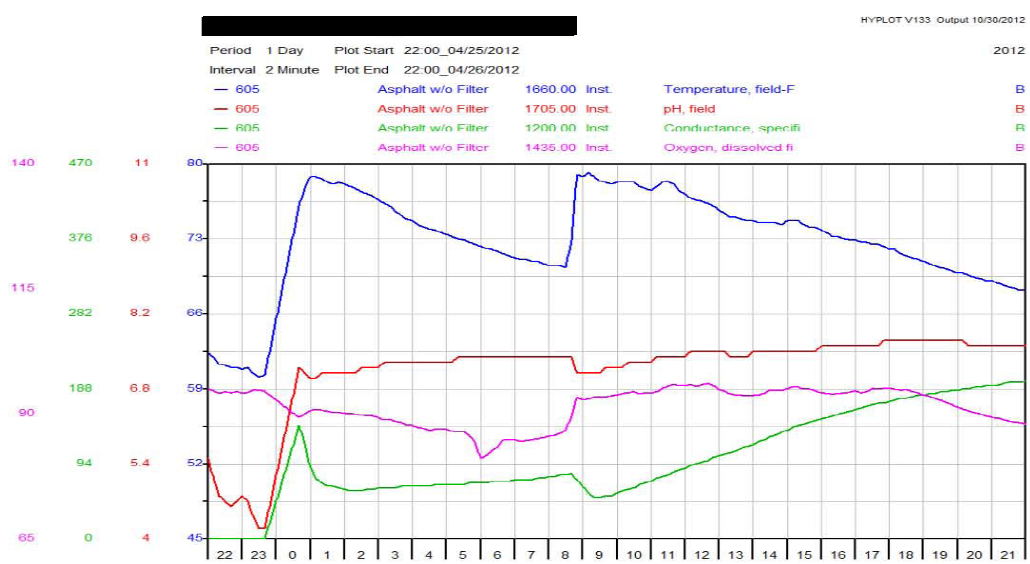




*Equipment malfunction-specific conductivity probe only recorded 0 when dry and 2 when wet

W-2 11-12 4/25/12 Sampled Event –Asphalt without Filter

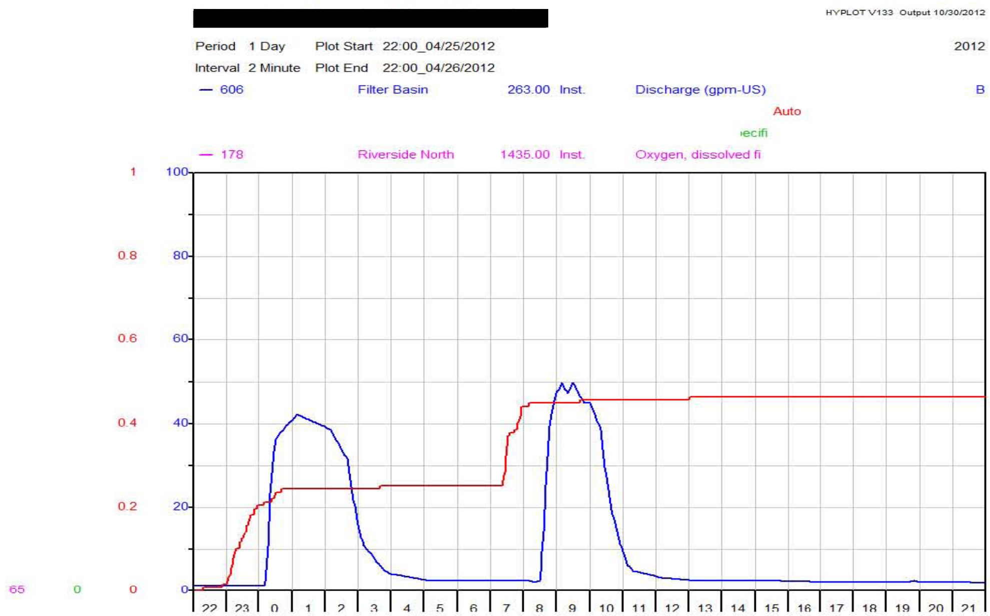
Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began- Isco (Time)	Lag Time (HR:Min)	Flow ended (Date Time)
605	Porous Asphalt without filter	0.25	0.22	1493.49	1438.40	55.09	3.69%	22:51 4/25/12	4/26/2012 0:10	1:19	*4/26/2012 8:30



W-2 11-12 4/25/12 Sampled Event –Infiltration Basin

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR:Min)	Flow ended (Date Time)
606	Filter Basin Sub drain	0.25	0.89	6041.83	7011.20	-969.37	(-16.04%)	22:51 4/25/12	4/26/2012 0:20	1:29	*4/26/2012 8:30:00 AM

*Mathematical gains can occur when the engineered drainage area become overwhelmed and more stormwater flows into the site

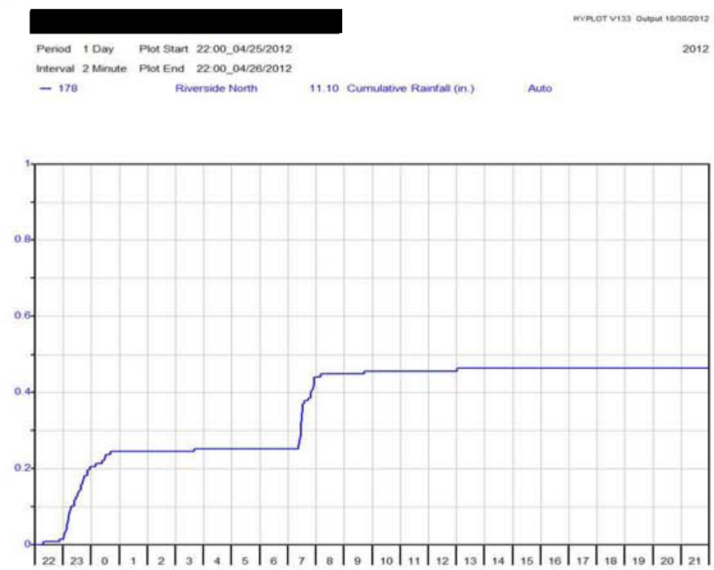


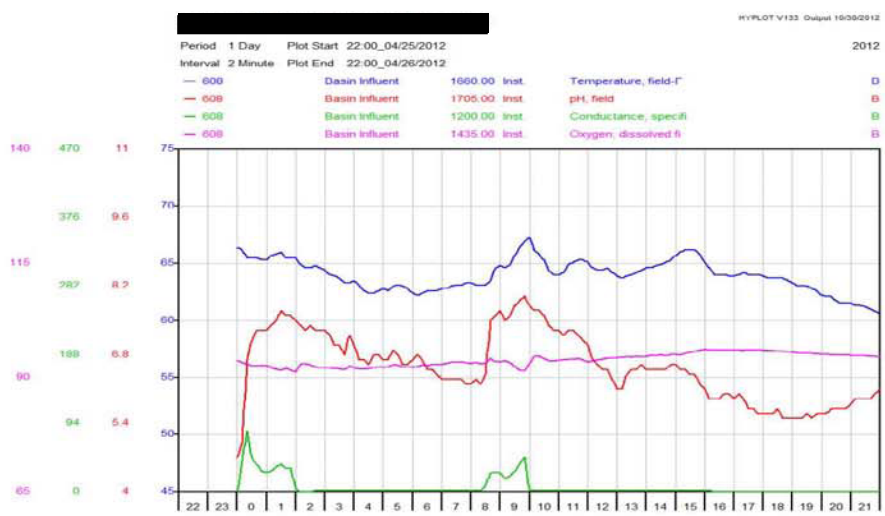
Equipment malfunction, no data from sonde recorded

W-2 11-12 4/25/12 Sampled Event –Infiltration Basin

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR:Min)	Flow ended (Date Time)
608	Filtration Basin Influent	0.25	0.89					22:51 4/25/12			

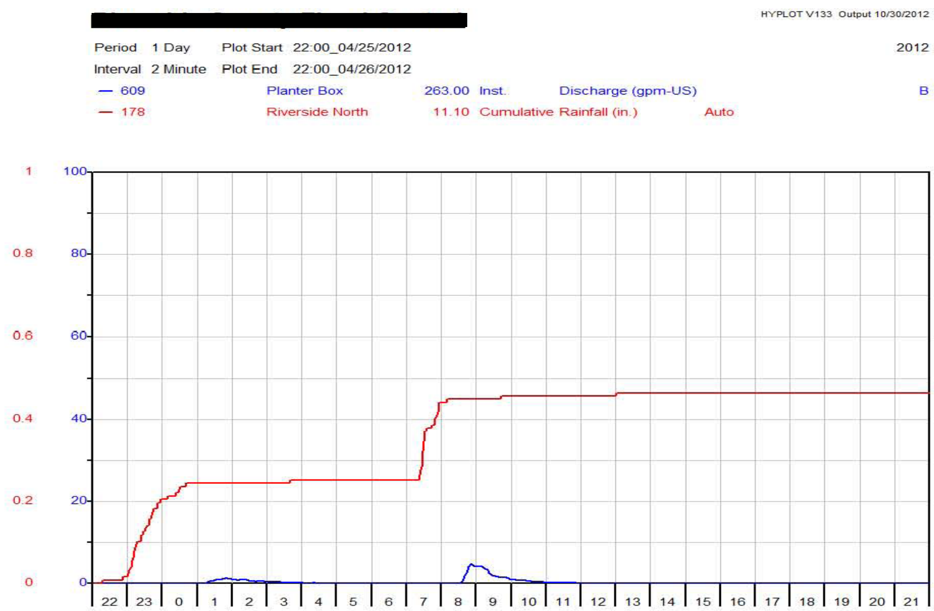
*Due to Construction plan changes, no accurate flow measurements recorded





W-2 11-12 4/25/12 Sampled Event –Infiltration Basin

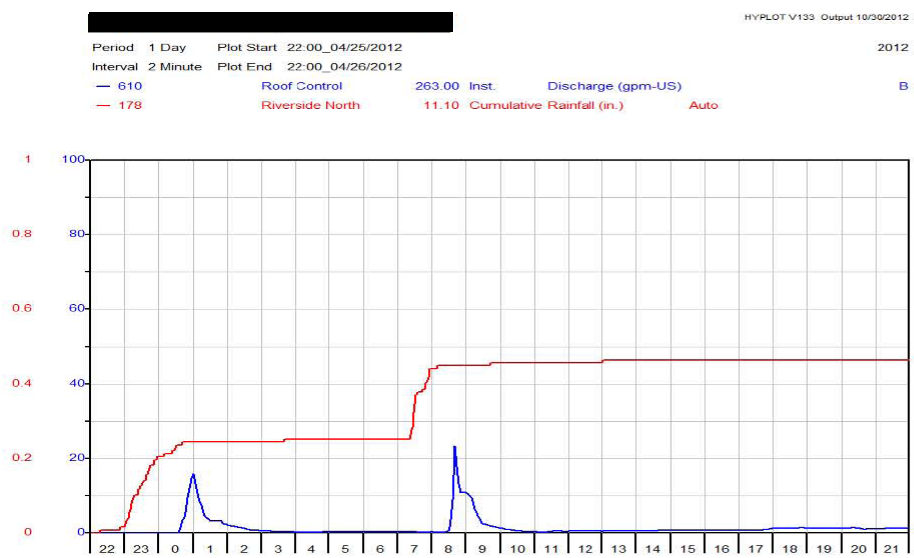
Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR:Min)	Flow ended (Date Time)
609	Rain Garden	0.25	0.13	882.51	100.94	781.57	88.56%	22:51 4/25/12	4/26/2012 1:10	2:19	*4/26/2012 8:30



Equipment malfunction, no data from sonde recorded

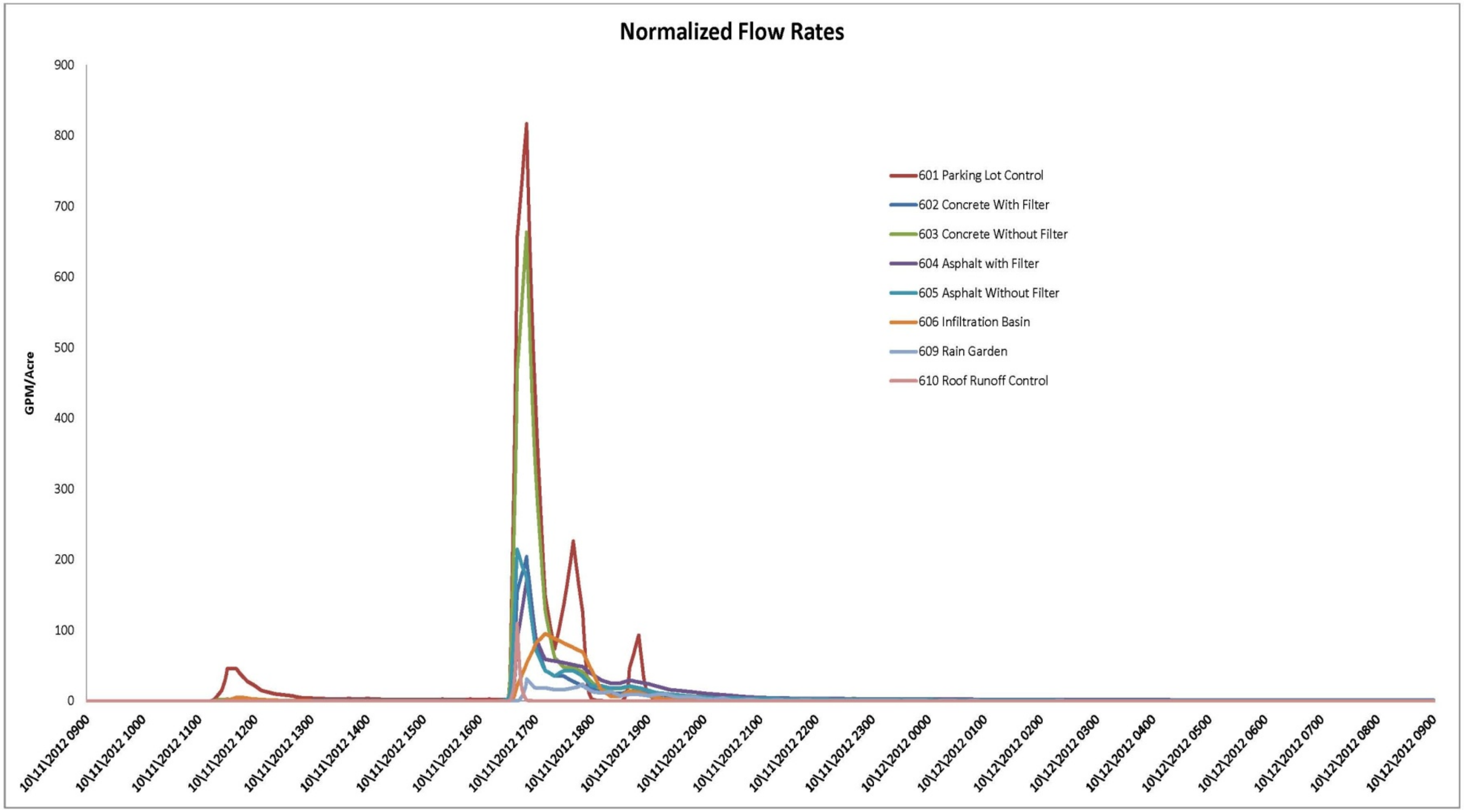
W-2 11-12 4/25/12 Sampled Event –Infiltration Basin

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR:Min)	Flow ended (Date Time)
610	Roof Runoff Control	0.25	0.13	882.51	670.55	211.96	24.02%	22:51 4/25/12	4/26/2012 0:40	1:49	*4/26/2012 8:30



Equipment malfunction, no data from sonde recorded

12-13 10/11/12 Storm Event



*No flow through 607 Infiltration Basin overflow. No accurate measurement of flow through 608 Infiltration Basin Influent.

12-13 10/11/12 Storm Event Pavement Control vs. Pavement BMP's

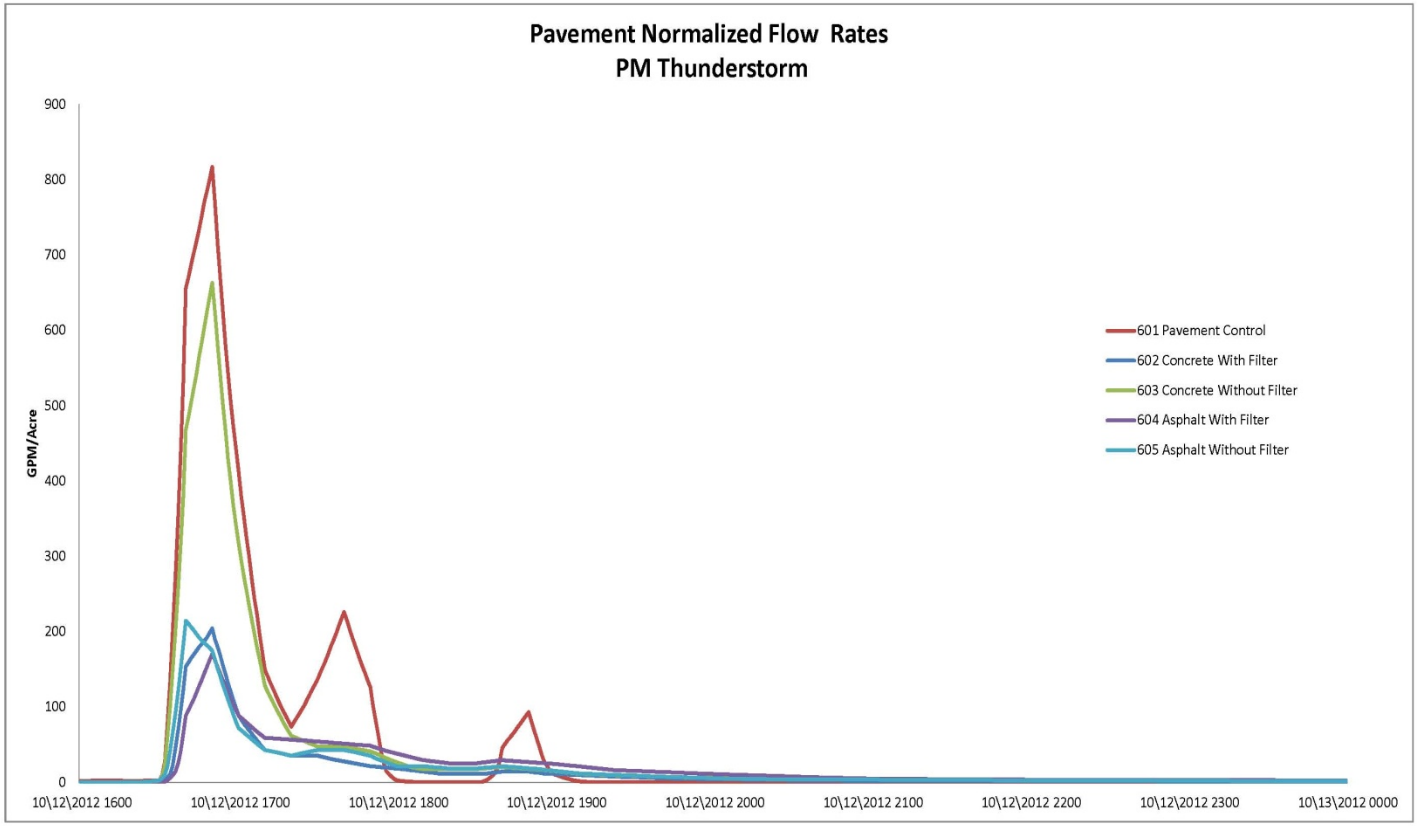
Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)
601	Parking lot Control	0.59	0.17	2723.57	4571.76	-1848.19	(-67.86%)
602	Porous Concrete with filter	0.59	0.22	3524.62	1709.5	1815.12	51.50%
603	Porous Concrete without filter	0.59	0.23	3684.84	5930	-2245.16	(-60.93%)
604	Porous Asphalt with filter	0.59	0.16	2563.36	1916.88	646.48	25.22%
605	Porous Asphalt without filter	0.59	0.22	3524.62	2422.96	1101.66	31.26%

Predicted AM Storm

Hydstra site ID	Description	Amount of Rain (inches)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes
601	Parking lot Control	0.04	11:02 10/11/12	11:10 10/11/2012	8
602	Porous Concrete with filter	0.04	11:02 10/11/12	11:30 10/11/2012	28
603	Porous Concrete without filter	0.04	11:02 10/11/12	11:20 10/11/2012	18
604	Porous Asphalt with filter	0.04	11:02 10/11/12	12:10 10/11/2012	52
605	Porous Asphalt without filter	0.04	11:02 10/11/12	12:20 10/11/2012	1hr 18min

PM Thunderstorm

Hydstra site ID	Description	Amount of Rain (inches)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes	Flow ended (Date Time)
601	Parking lot Control	0.55	16:18 10/11/12	16:30	12	17:50 10/11/2012
602	Porous Concrete with filter	0.55	16:18 10/11/12	16:30	12	*10:00 10/12/2012
603	Porous Concrete without filter	0.55	16:18 10/11/12	16:30	12	10:10 10/26/2012
604	Porous Asphalt with filter	0.55	16:18 10/11/12	16:40	22	5:10 10/14/2012
605	Porous Asphalt without filter	0.55	16:18 10/11/12	16:30	12	1:40 10/23/12



*Calculated drainage areas were overwhelmed by intense rain, increasing the amount of water which flowed through some sites (601 & 603) and decreasing flow through others (602)

12-13 10/11/12 Storm Event Pavement Control vs. Infiltration Basin BMP

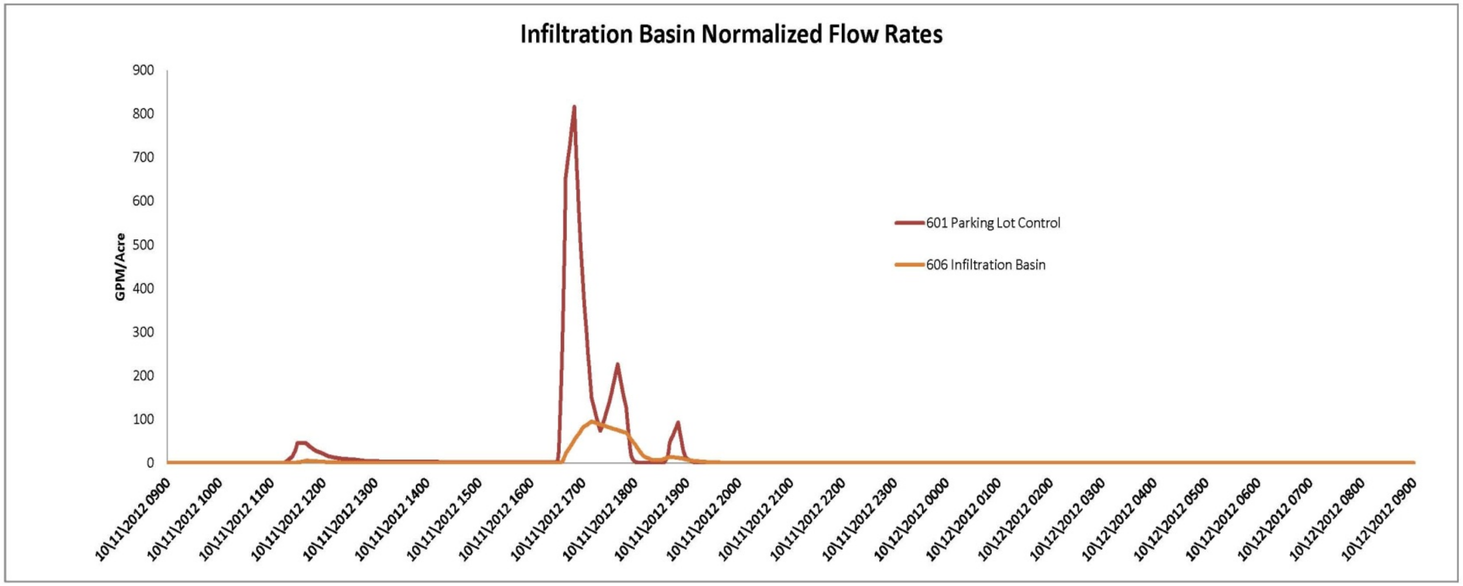
Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)
601	Parking lot Control	0.59	0.17	2723.57	4571.76	-1848.18	-67.86%
606	Infiltration Basin Sub drain	0.59	0.89	14258.71	6627.18	7631.53	53.52%

Predicted AM Storm

Hydstra site ID	Description	Amount of Rain (inches)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes
601	Parking lot Control	0.04	11:02 10/11/12	11:10 10/11/2012	8
606	Infiltration Basin Sub drain	0.04	11:02 10/11/12	11:30 10/11/2012	28

PM Thunderstorm

Hydstra site ID	Description	Amount of Rain (inches)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes	Flow ended (Date Time)
601	Parking lot Control	0.55	16:18 10/11/12	16:30	12	17:50 10/11/2012
606	Infiltration Basin Sub drain	0.55	16:18 10/11/12	16:40	22	3:30 10/29/2012

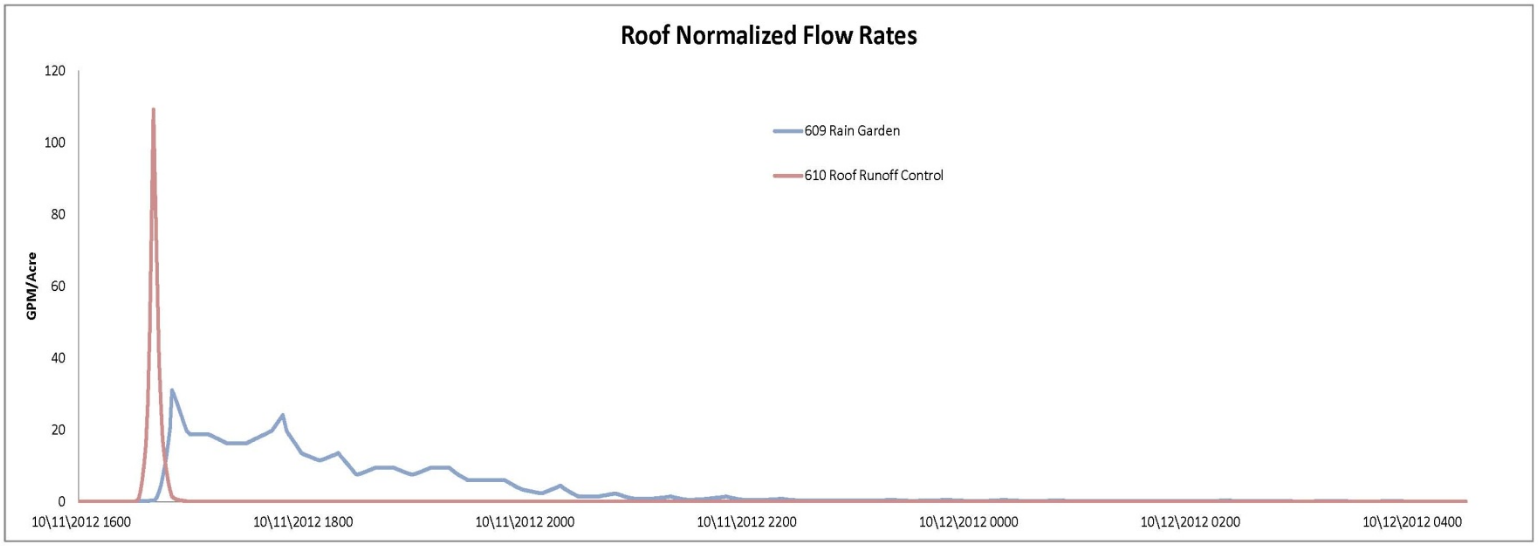


*Infiltration Basin is compared to Pavement Control site as no accurate flow measurements for Basin Influent are possible at this time.

12-13 10/11/12 Storm Event Roof Control vs. Roof BMP

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes	Flow ended (Date Time)
609	Rain Garden	0.59	0.13	2082.73	353.88	1728.85	83.01%*	11:02 (0.04)	10/11/2012 16:40	22	10/12/2012 6:20
610	Roof Runoff Control	0.59	0.13	2082.73	73.56	2009.17	96.47%*	16:18-18:31 (0.55)	10/11/2012 16:40	22	10/11/2012 17:00

*No flow during morning predicted storm. Roof drains may have been overwhelmed by intensity of afternoon thunder storm leading to losses through secondary drains. In 610 the plug was (assumed to be) disrupted by water flow leading to water flowing out drain rather than being measured over the weir.

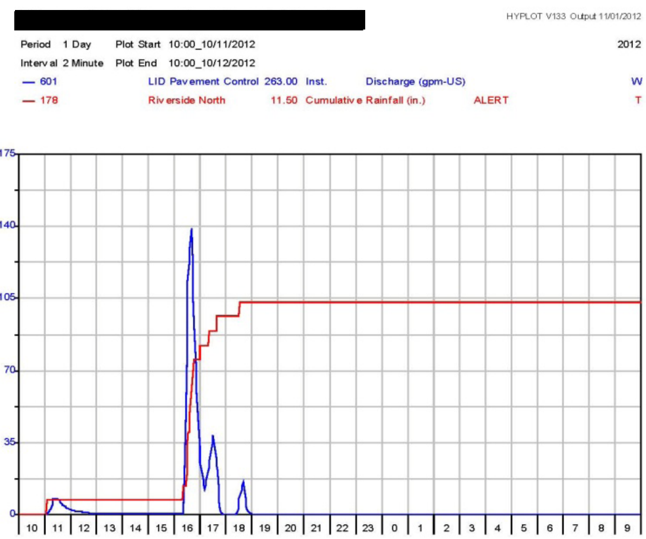


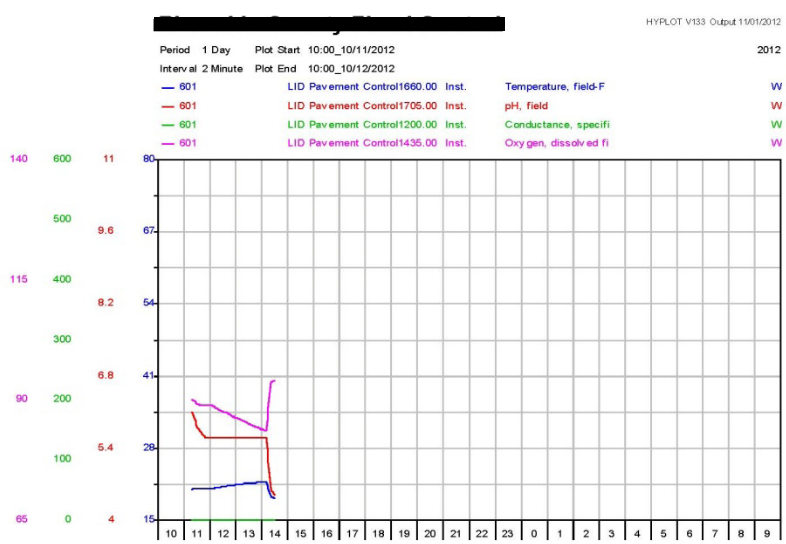
*Possible inaccuracies associated with loss of stormwater through secondary piping due to intensity of storm and equipment failure of drain plug in 610.

12-13 10/11/12 Storm Event -Pavement Control

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
601	Parking lot Control	0.59	0.17	2723.57	4571.76	-1848.19	(-67.86%)	11:02 10/11	11:10 10/11	8	--
								16:18 10/11	16:30 10/11	12	17:50 10/11

*Mathematical gains can occur when the engineered drainage area become overwhelmed and more stormwater flows into the site

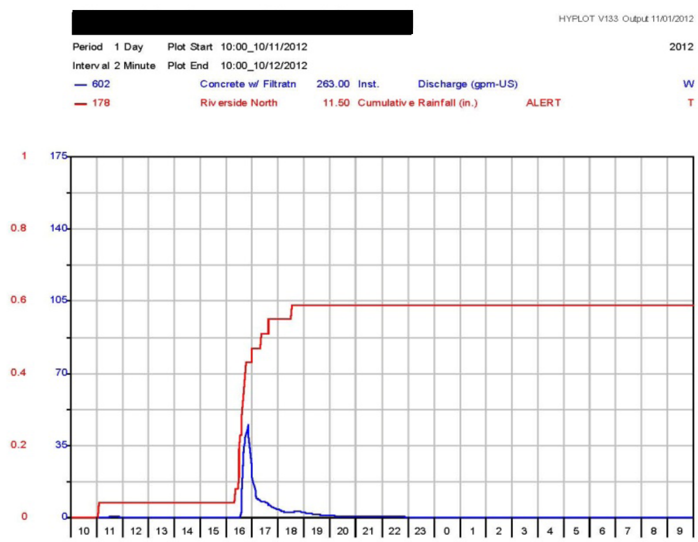


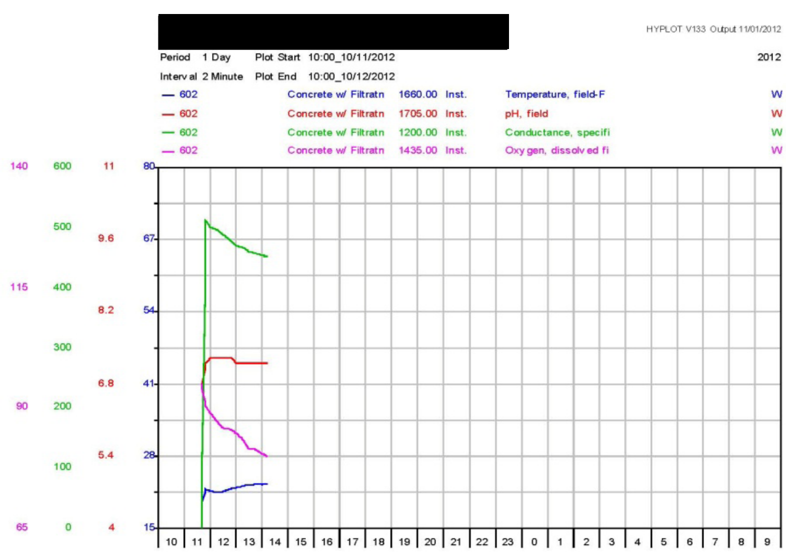


*Sonde was deployed only during AM storm

12-13 10/11/12 Storm Event –Concrete with Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
602	Porous Concrete with filter	0.59	0.22	3524.62	1709.5	1815.12	51.50%	11:02 10/11	11:30 10/11	28	--
								16:18 10/11	16:30	12	*10:00 10/12

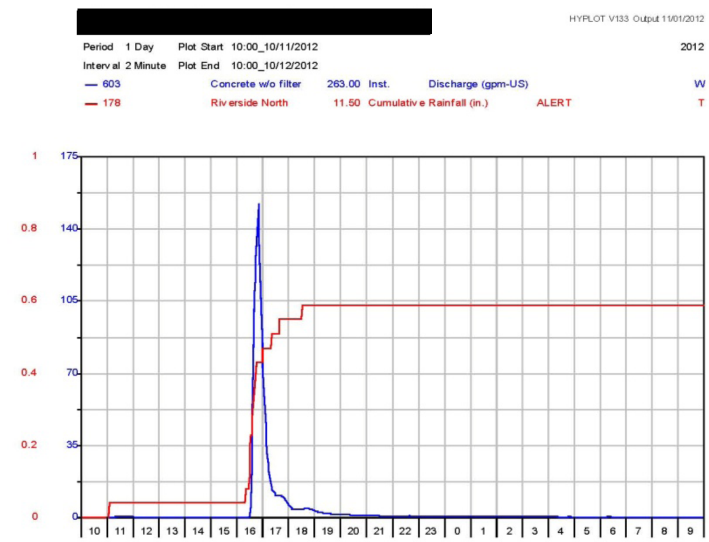


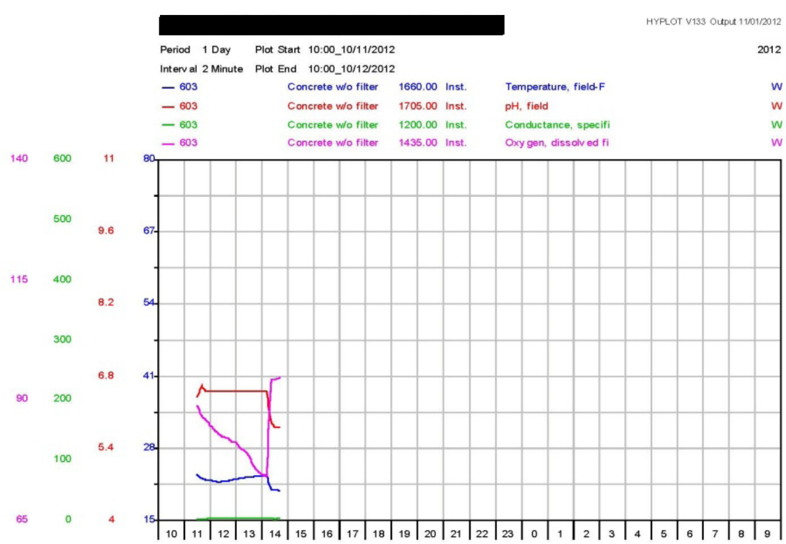


*Sonde was deployed only during AM storm

12-13 10/11/12 Storm Event –Concrete without Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
603	Porous Concrete without filter	0.59	0.23	3684.84	5930	-2245.16	(-60.93%)	11:02 10/11	11:20 10/11	18	--
								16:18 10/11	16:30	12	10:10 10/26

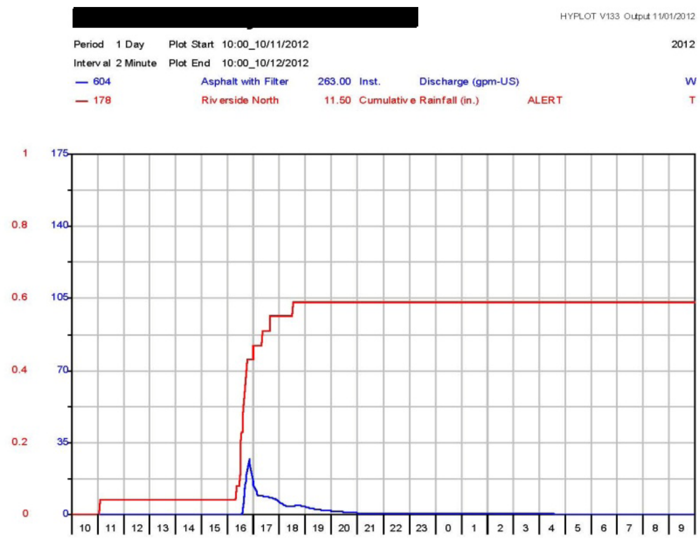


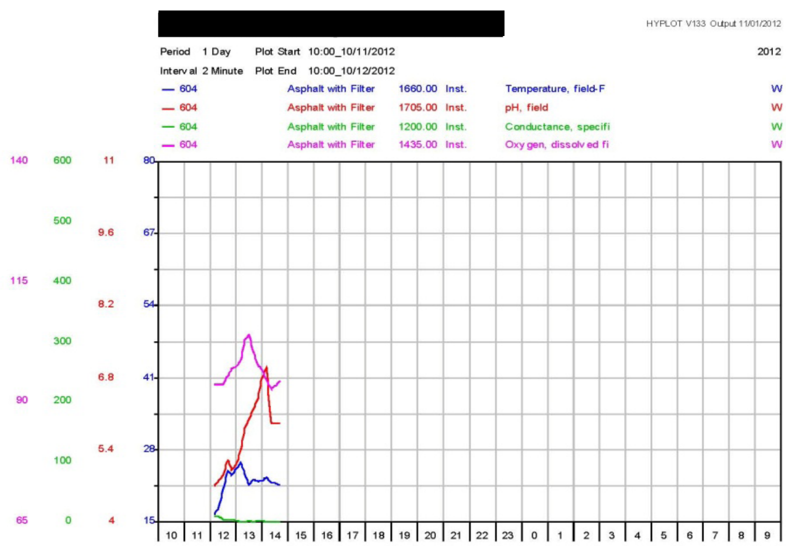


*Sonde was deployed only during AM storm

12-13 10/11/12 Storm Event –Asphalt with Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
604	Porous Asphalt with filter	0.59	0.16	2563.36	1916.88	646.48	25.22%	11:02 10/11	12:10 10/11	52	--
								16:18 10/11	16:40	22	5:10 10/14

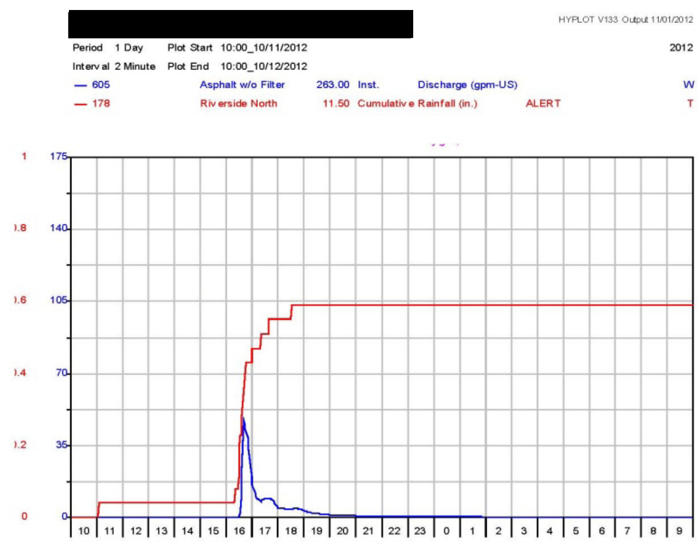


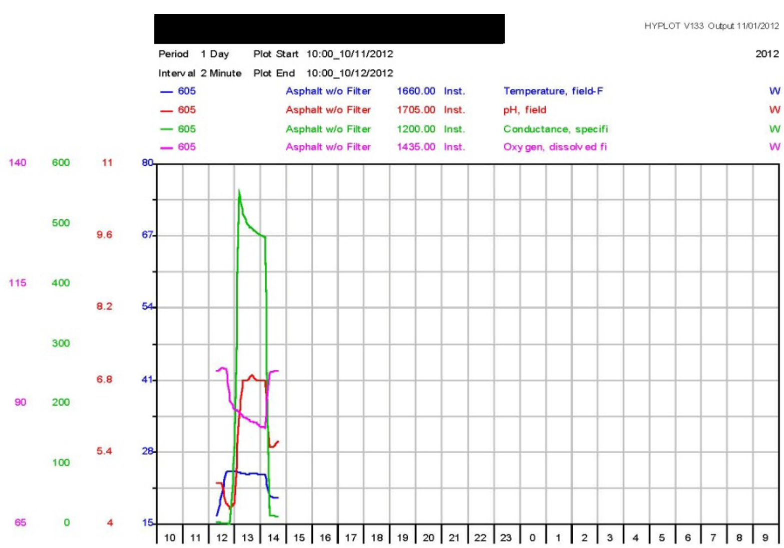


*Sonde was deployed only during AM storm

12-13 10/11/12 Storm Event –Asphalt without Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
605	Porous Asphalt without filter	0.59	0.22	3524.62	2422.96	1101.66	31.26%	11:02 10/11	12:20 10/11	1hr 18min	--
								16:18 10/11	16:30	12	1:40 10/23

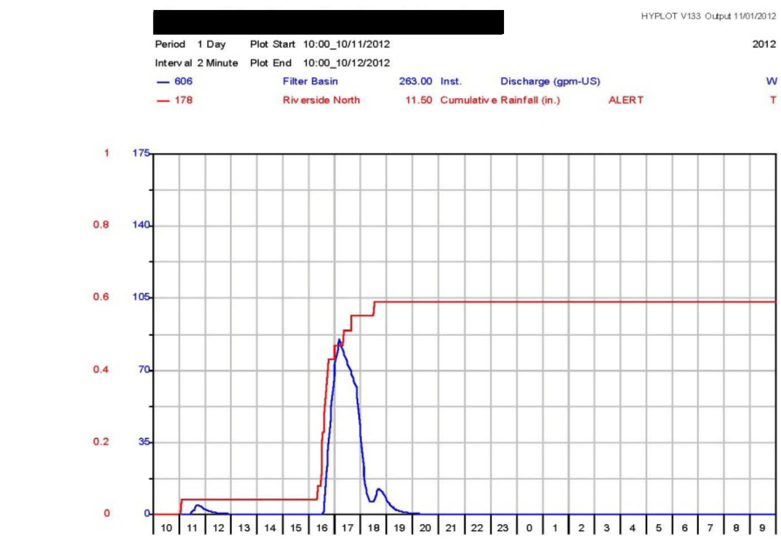


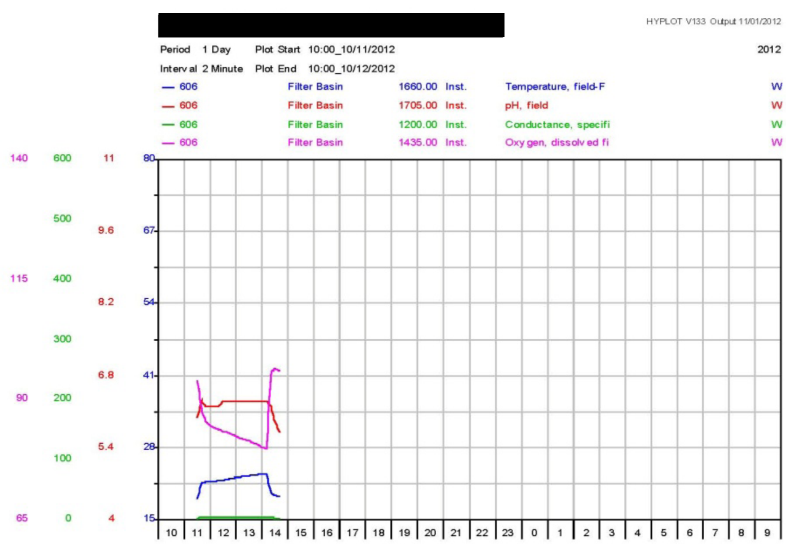


*Sonde was deployed only during AM storm

12-13 10/11/12 Storm Event –Infiltration Basin

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
606	Infiltration Basin Sub drain	0.59	0.89	14258.71	6627.18	7631.53	53.52%	11:02 10/11	11:10 10/11	8	--
								16:18 10/11	16:40	22	3:30 10/29/2012



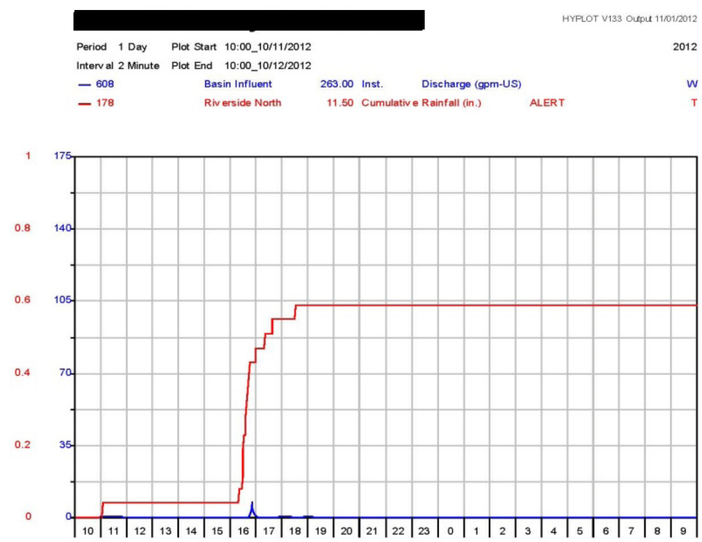


*Sonde was deployed only during AM storm

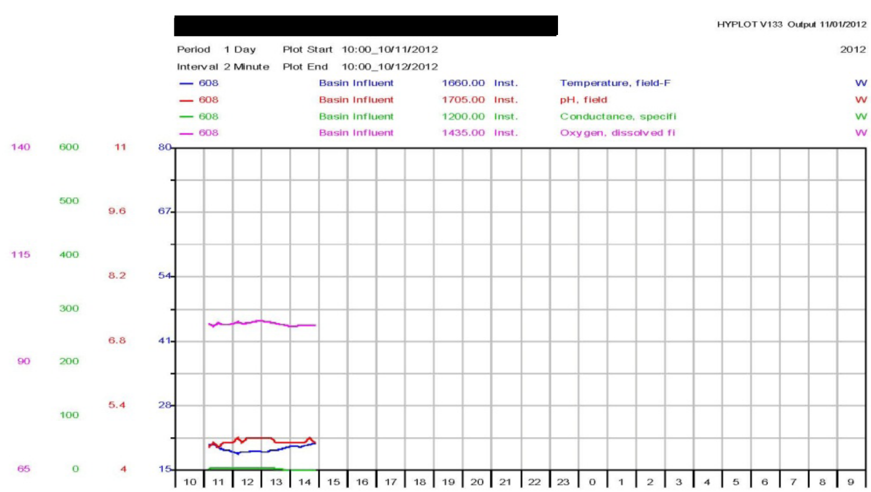
12-13 10/11/12 Storm Event –Infiltration Basin

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
608	Filtration Basin Influent	0.59	0.89	14258.71				11:02 10/11	--	--	--
								16:18 10/11	--	--	--

*Due to Construction plan changes, no accurate flow measurements recorded



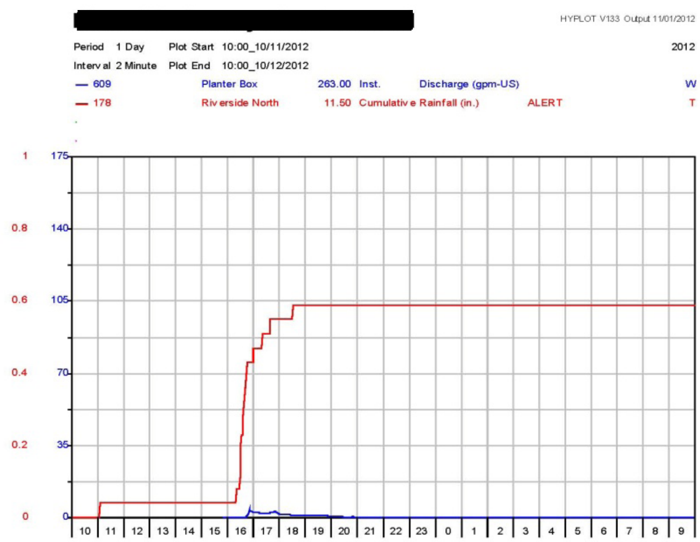
*Due to construction changes in sampling vault, flow measurements are not accurate and should not be used for analysis



*Sonde was deployed only during AM storm

12-13 10/11/12 Storm Event –Infiltration Basin

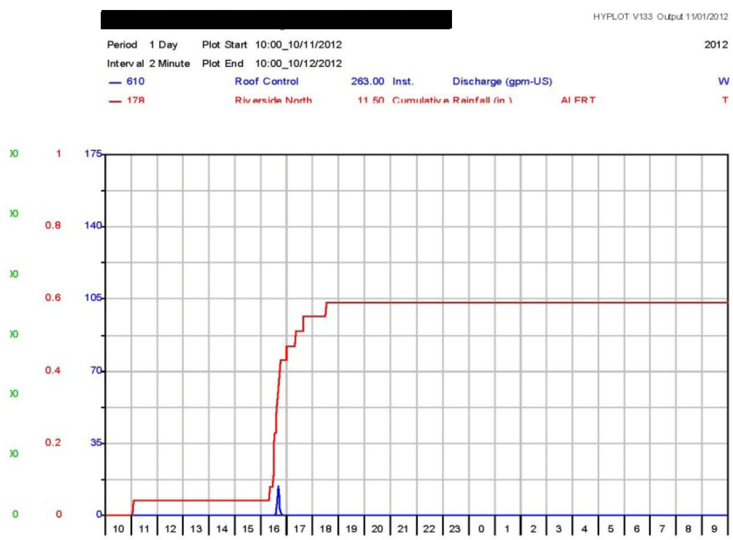
Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
609	Rain Garden	0.59	0.13	2082.73	353.88	1728.85	83.01%*	11:02 10/11	--	--	--
								16:18 10/11	16:40 10/11	22	06:20 10/12



Sonde was deployed only during AM storm and there was not enough stormwater flow for any measurements.

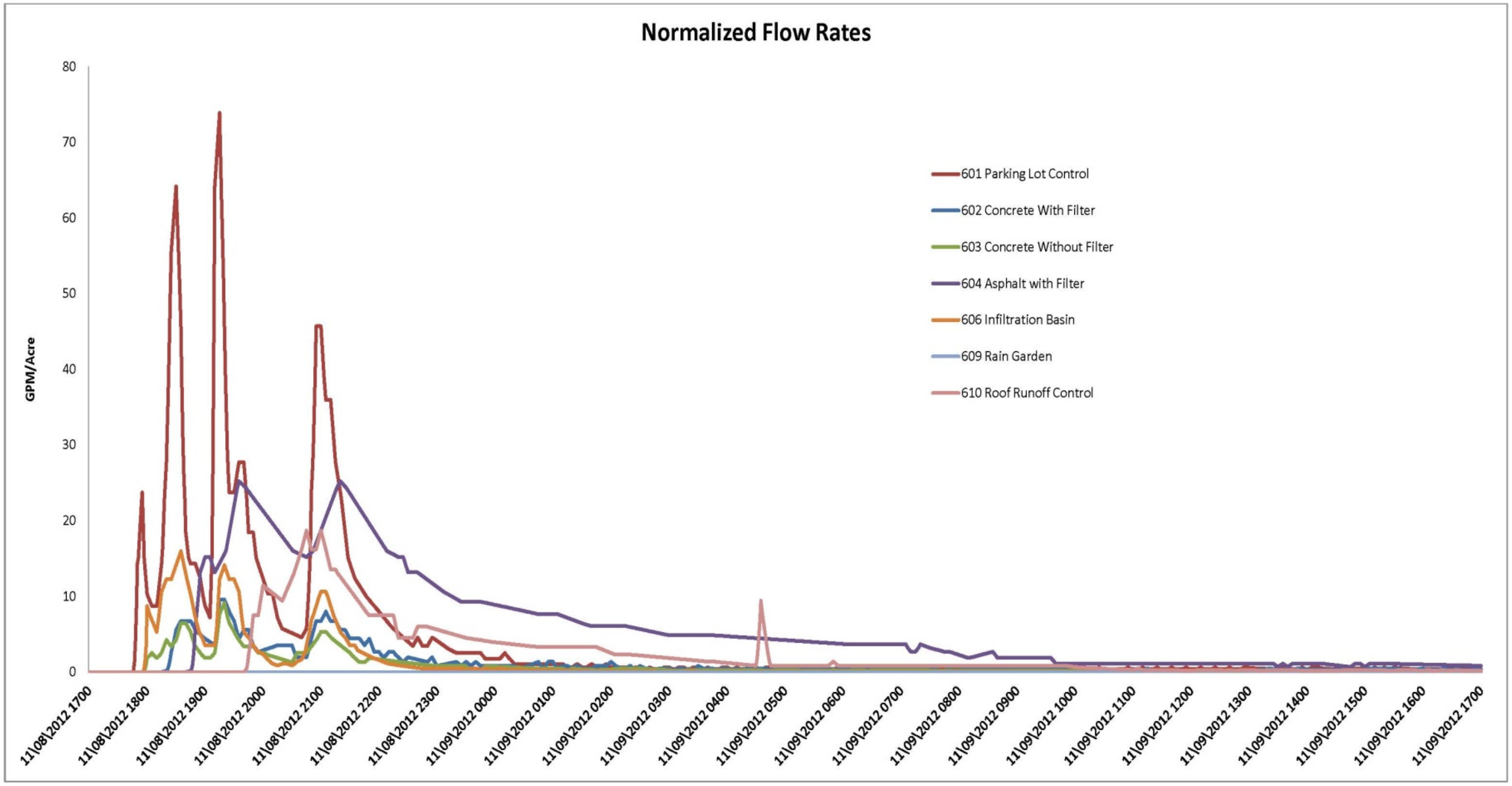
12-13 10/11/12 Storm Event –Infiltration Basin

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
610	Roof Runoff Control	0.59	0.13	2082.73	73.56	2009.17	96.47%*	11:02 10/11	--	--	--
								16:18 10/11	16:40 10/11	22	17:00 10/11



Sonde was deployed only during AM storm and there was not enough stormwater flow for any measurements.

12-13 11/8/12 Storm Event

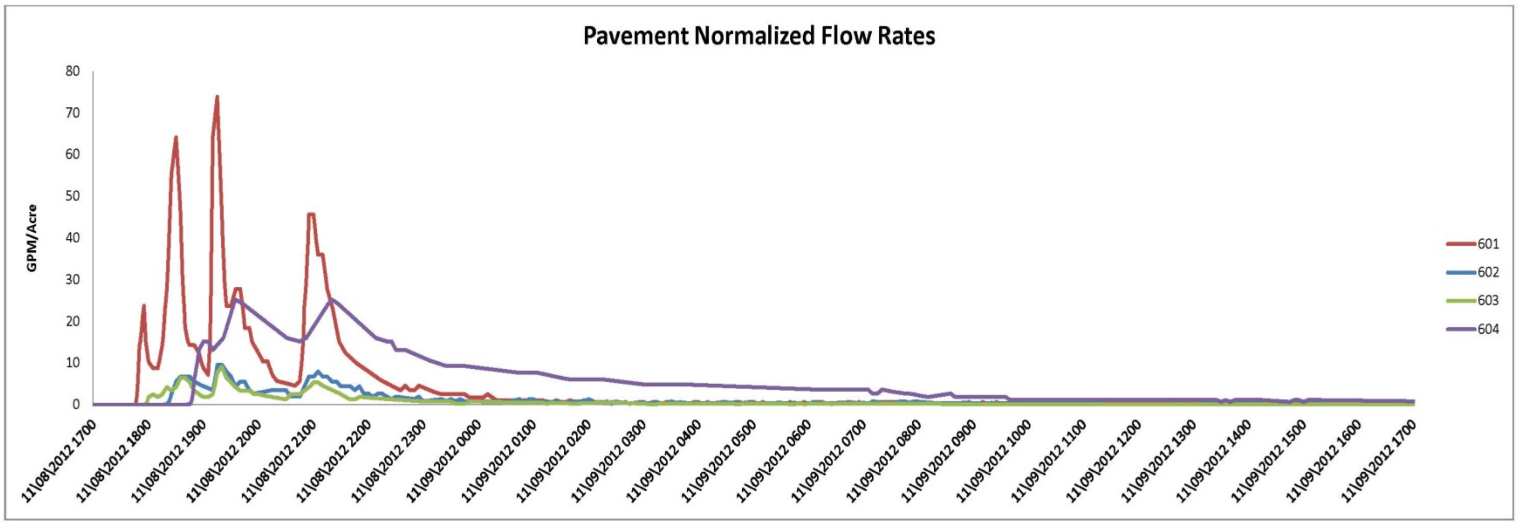


*No flow data shown from 605 due to equipment malfunction. Looking into accuracy of 604 data, equipment seems to be functioning but graph looks odd.

12-13 11/8/12 Storm Event Pavement Control vs. Pavement BMP's

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes	Flow ended (Date Time)
601	Parking lot Control	0.19	0.17	877.08	1176.99	-299.91	(-34.19%)	17:33 11/8/12	11/8/2012 17:50	17	11/12/2012 3:15
602	Porous Concrete with filter	0.19	0.22	1135.05	404.9	730.15	64.33%	17:33 11/8/12	11/8/2012 18:10	37	11/10/2012 1:30*
603	Porous Concrete without filter	0.19	0.23	1186.64	304.18	882.46	74.37%	17:33 11/8/12	11/8/2012 18:00	27	11/10/12 1200*
604	Porous Asphalt with filter	0.19	0.16	825.49	1384.47	-558.98	(-67.71%)	17:33 11/8/12	11/8/2012 18:45	72	11/11/2012 7:25
605	Porous Asphalt without filter	0.19	0.22	1135.05				17:33 11/8/12	11/8/2012 18:30	57	

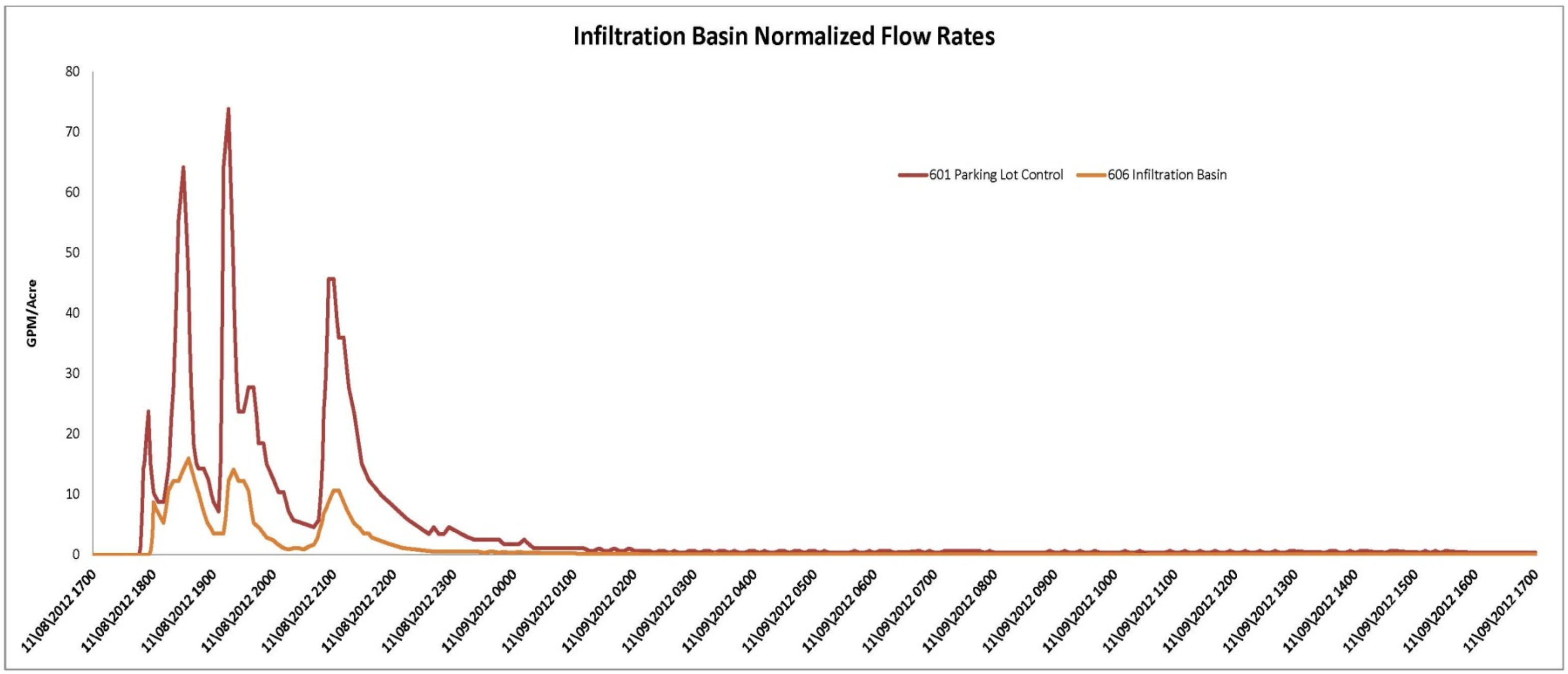
*Approximate time base flow reached



*No flow data shown from 605 due to equipment malfunction. Looking into accuracy of 604 data, equipment seems to be functioning but graph looks odd.

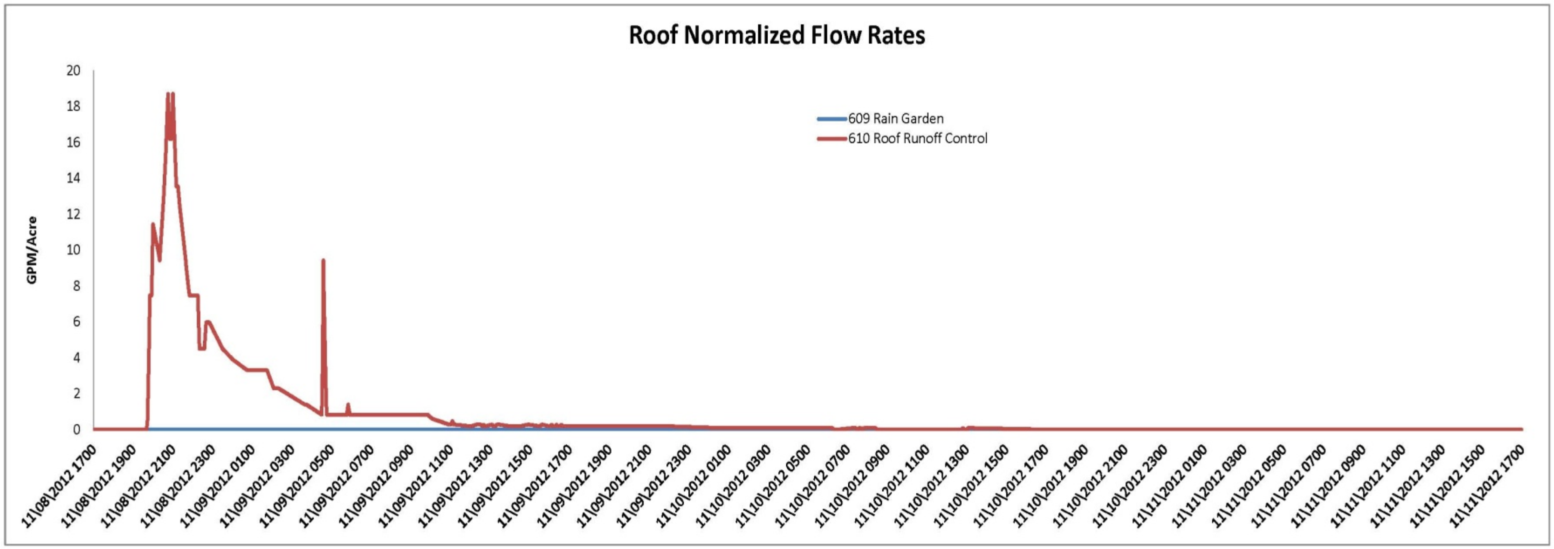
12-13 11/8/12 Storm Event Pavement Control vs. Infiltration Basin BMP

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes	Flow ended (Date Time)
601	Parking lot Control	0.19	0.17	877.08	1176.99	-299.91	(-34.19%)	17:33 11/8/12	11/8/2012 17:50	17	11/12/2012 3:15
606	Infiltration Basin Sub drain	0.19	0.89	4591.79	1494.99	3096.80	67.44%		11/8/2012 18:00	27	11/11/12 2:00



12-13 11/8/12 Storm Event Roof Control vs. Roof BMP

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes	Flow ended (Date Time)
609	Rain Garden	0.19	0.13	670.71	0	670.71	100.00%		--	--	--
610	Roof Runoff Control	0.19	0.13	670.71	448.14	222.57	33.18%	11/8/2012 17:33	11/8/2012 19:45	132	11/10/2012 21:10

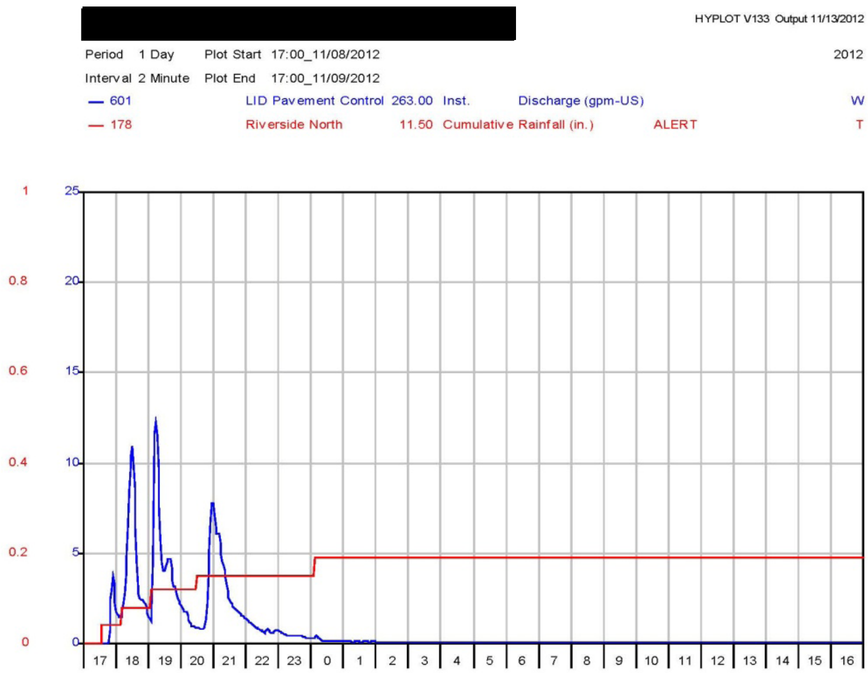


*No flow measured through 609; 100% retention

12-13 11/8/12 Storm Event -Pavement Control

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
601	Parking lot Control	0.19	0.17	877.08	1176.99	-299.90	(-34.19%)	11/8/12 17:33	11/8/12 17:50	17	11/12/12 3:15

*Mathematical gains can occur when the engineered drainage area become overwhelmed and more stormwater flows into the site



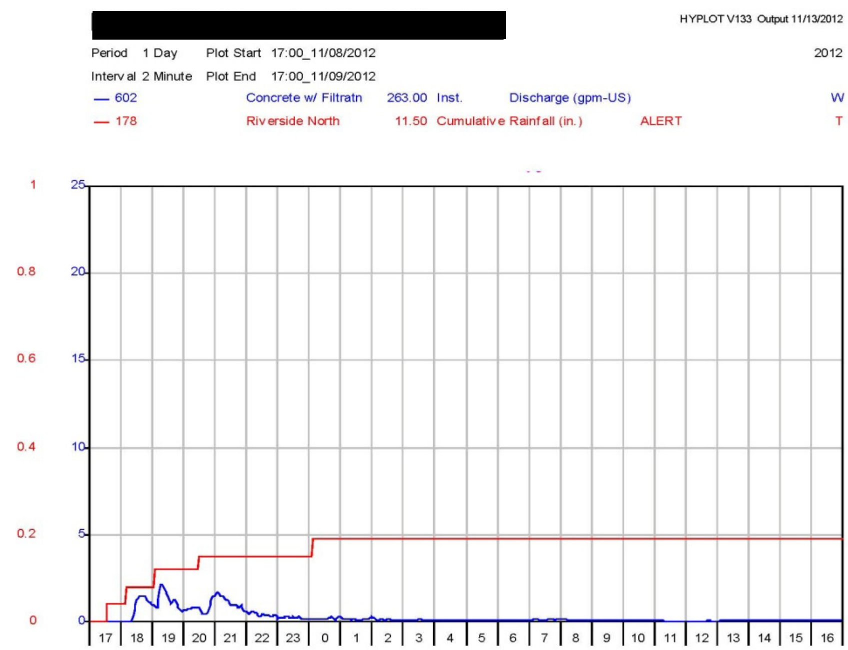
*Small storm event discharge scale ~¼ of past events

*Sonde was not deployed

12-13 11/8/12 Storm Event –Concrete with Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
602	Porous Concrete with filter	0.19	0.22	1135.05	404.9	730.15	64.33%	17:33 11/8/12	11/8/2012 18:10	37	11/10/2012 1:30*

*Approximate time base flow reached



*Small storm event discharge scale ~¼ of past events

*Sonde was not deployed

12-13 11/8/12 Storm Event –Concrete without Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
603	Porous Concrete without filter	0.19	0.23	1186.64	304.18	882.46	74.37%	17:33 11/8/12	11/8/2012 18:00	27	11/10/12 1200*

*Approximate time base flow reached

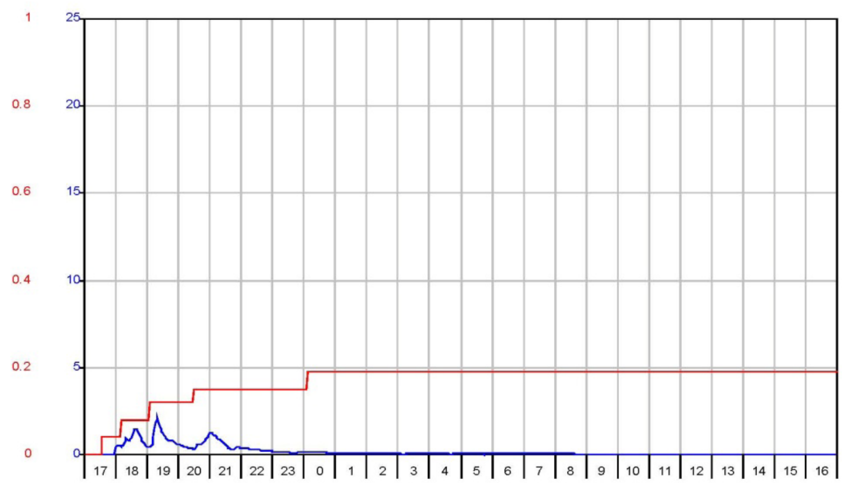
[redacted] HYPLOT V133 Output 11/13/2012

Period 1 Day Plot Start 17:00_11/08/2012 2012

Interval 2 Minute Plot End 17:00_11/09/2012

— 603 Concrete w/o filter 263.00 Inst. Discharge (gpm-US) W

— 178 Riverside North 11.50 Cumulative Rainfall (in.) ALERT T

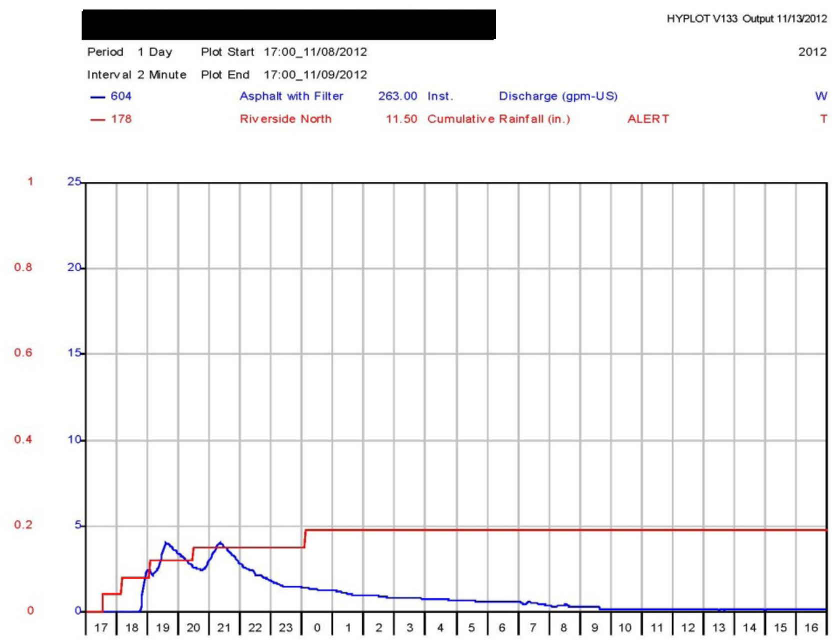


*Small storm event discharge scale ~¼ of past events

*Sonde was not deployed

12-13 11/8/12 Storm Event –Asphalt with Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
604	Porous Asphalt with filter	0.19	0.16	825.49	1384.47	-558.98	(-67.71%)	17:33 11/8/12	11/8/2012 18:45	72	11/11/12 7:25



*Small storm event discharge scale ~¼ of past events

*Sonde was not deployed

12-13 11/8/12 Storm Event –Asphalt without Filter

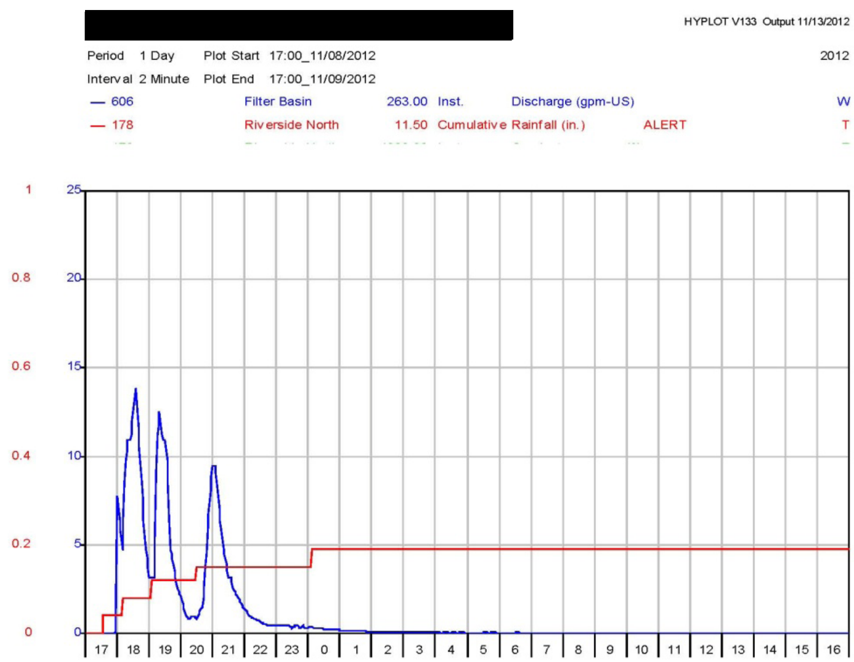
Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
605	Porous Asphalt without filter	0.19	0.22	1135.05				17:33 11/8/12	11/8/2012 18:30	57	

*Due to flow meter equipment malfunction no accurate flow measurements were recorded

*Sonde was not deployed

12-13 11/8/12 Storm Event –Infiltration Basin

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
606	Infiltration Basin Sub drain	0.19	0.89	4591.79	1494.99	3096.80	67.44%	11/8/2012 17:33	11/8/2012 18:00	27	11/11/12 2:00



*Small storm event discharge scale ~¼ of past events

*Sonde was not deployed

12-13 11/8/12 Storm Event –Infiltration Basin Influent

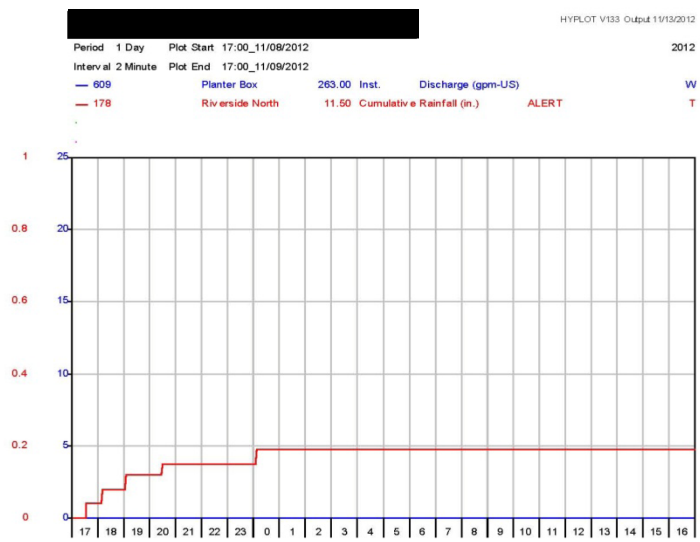
Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
608	Filtration Basin Influent	0.59	0.89	14258.71				11/8/2012 17:33	--	--	--

*Due to Construction plan changes, no accurate flow measurements recorded

*Due to construction changes in sampling vault, flow measurements are not accurate and should not be used for analysis

12-13 11/8/12 Storm Event –Rain Garden

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
609	Rain Garden	0.19	0.13	670.71	0	670.71	100.00%	11/8/2012 17:33	--	--	--

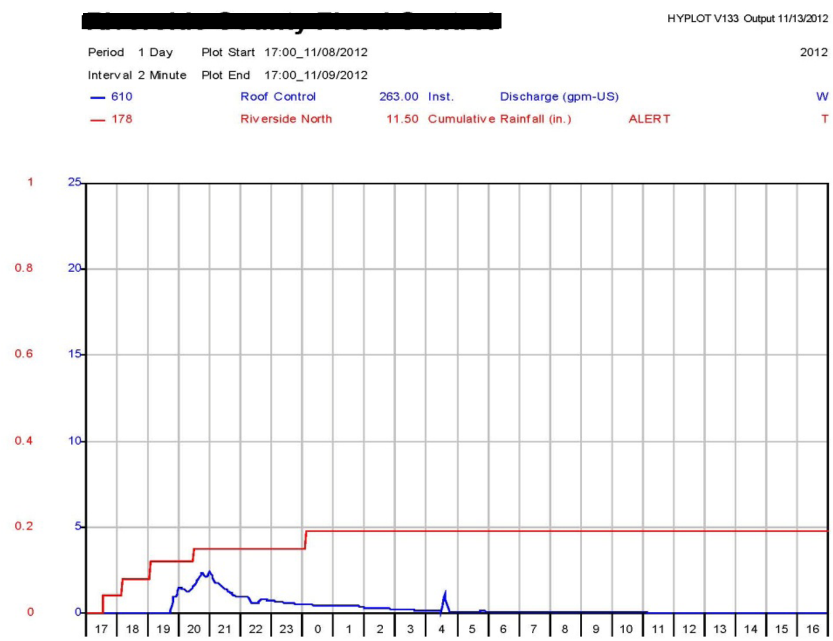


*Small storm event discharge scale ~¼ of past events; No discharge measured from 609

*Sonde was not deployed

12-13 10/11/12 Storm Event –Roof Runoff Control

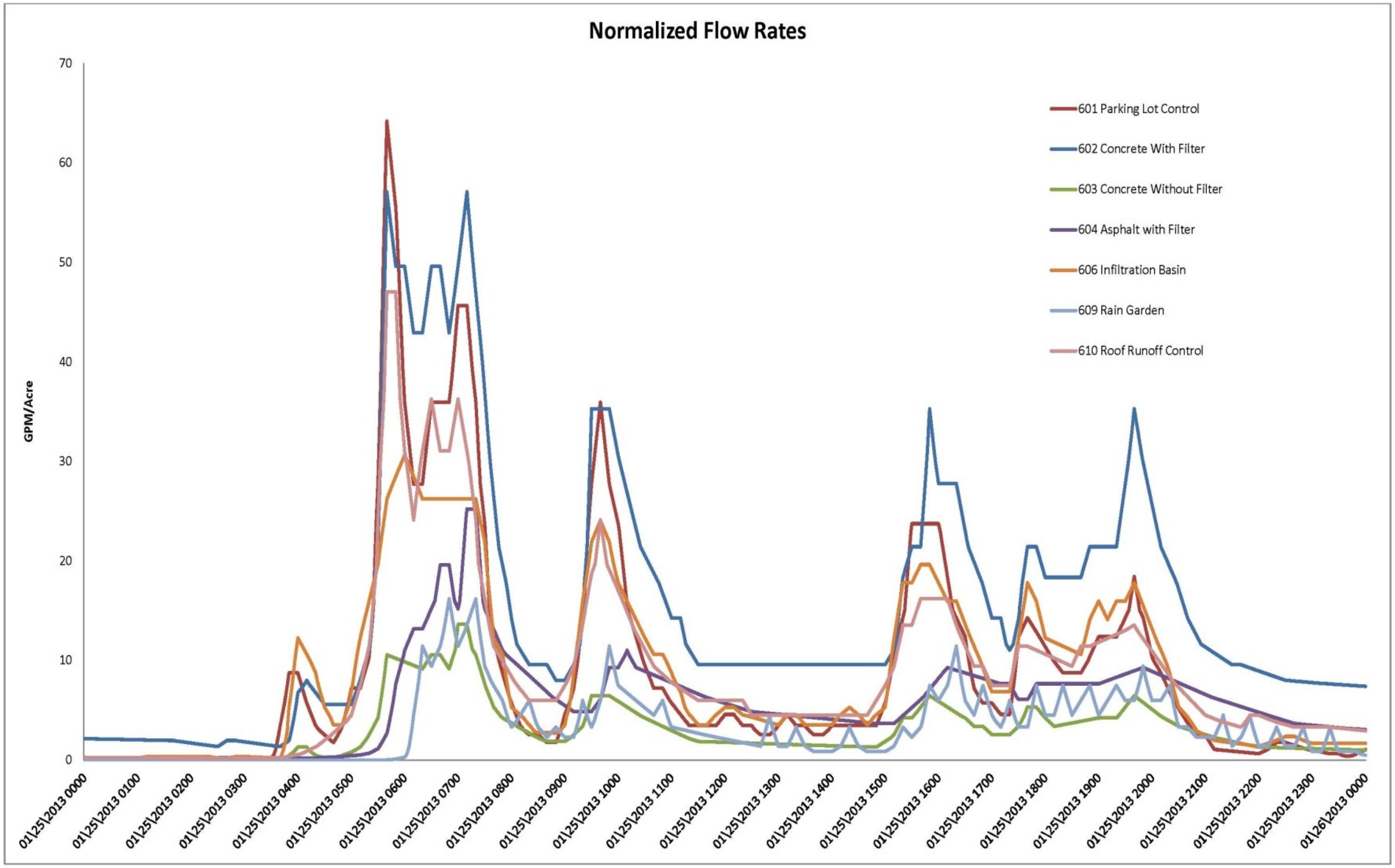
Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
610	Roof Runoff Control	0.19	0.13	670.71	448.14	222.57	33.18%	11/8/2012 17:33	11/8/2012 19:45	132	11/10/2012 21:10



*Small storm event discharge scale ~¼ of past events

*Sonde was not deployed

12-13 01/25/13 Sampled Storm Event



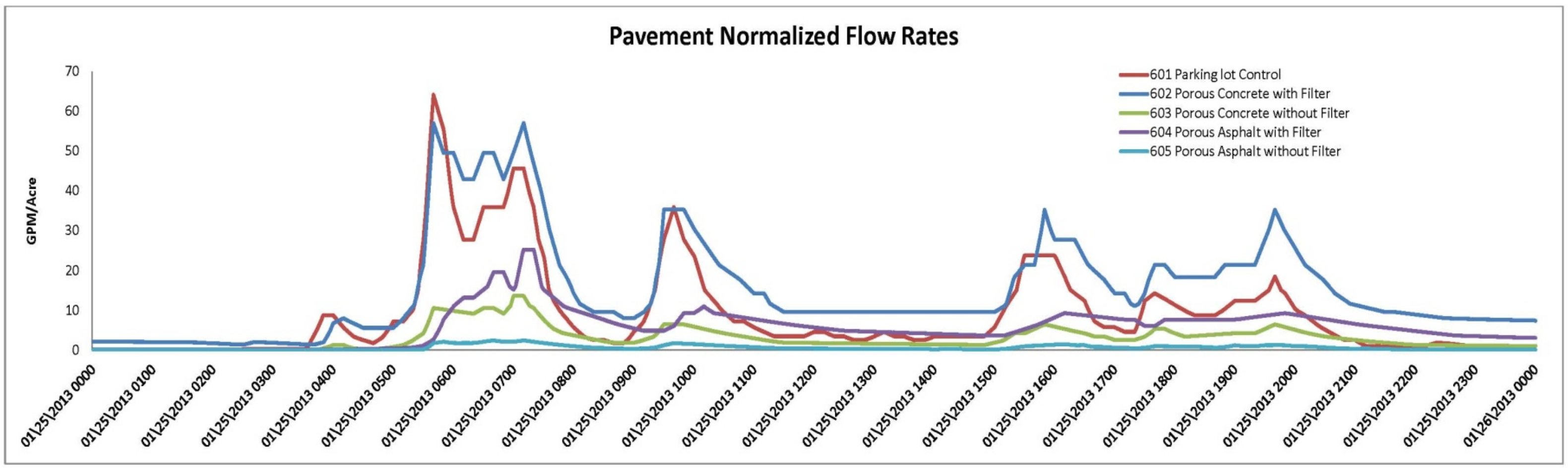
12-13 01/25/13 Sampled Storm Event Pavement Control vs. Pavement BMP's

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes	Flow ended (Date Time)
601	Parking lot Control	0.52	0.17	2400.44	2258.01	142.43	5.93%	03:16 1/25	03:40 1/25	24	23:50 1/26
602	Porous Concrete with filter	0.52	0.22	3106.45	5555	-2448.55	(-78.82%)*	03:16 1/25	03:50 1/25	34	12:00 1/26**
603	Porous Concrete without filter	0.52	0.23	3247.65	1229.04	2018.61	62.16%	03:16 1/25	03:30 1/25	14	10:19 1/31* still flowing
604	Porous Asphalt with filter	0.52	0.16	2259.24	1705	554.24	24.53%	03:16 1/25	04:10 1/25	54	13:30 1/31 * still flowing
605	Porous Asphalt without filter	0.52	0.22	3106.45	1132.5†	1973.95	63.54%	03:16 1/25	03:50 1/25	34	13:30 1/31 * still flowing

*Influenced by .17" of rain which fell on 1/24 and base flow from irrigation system

**Approximate time base flow reached

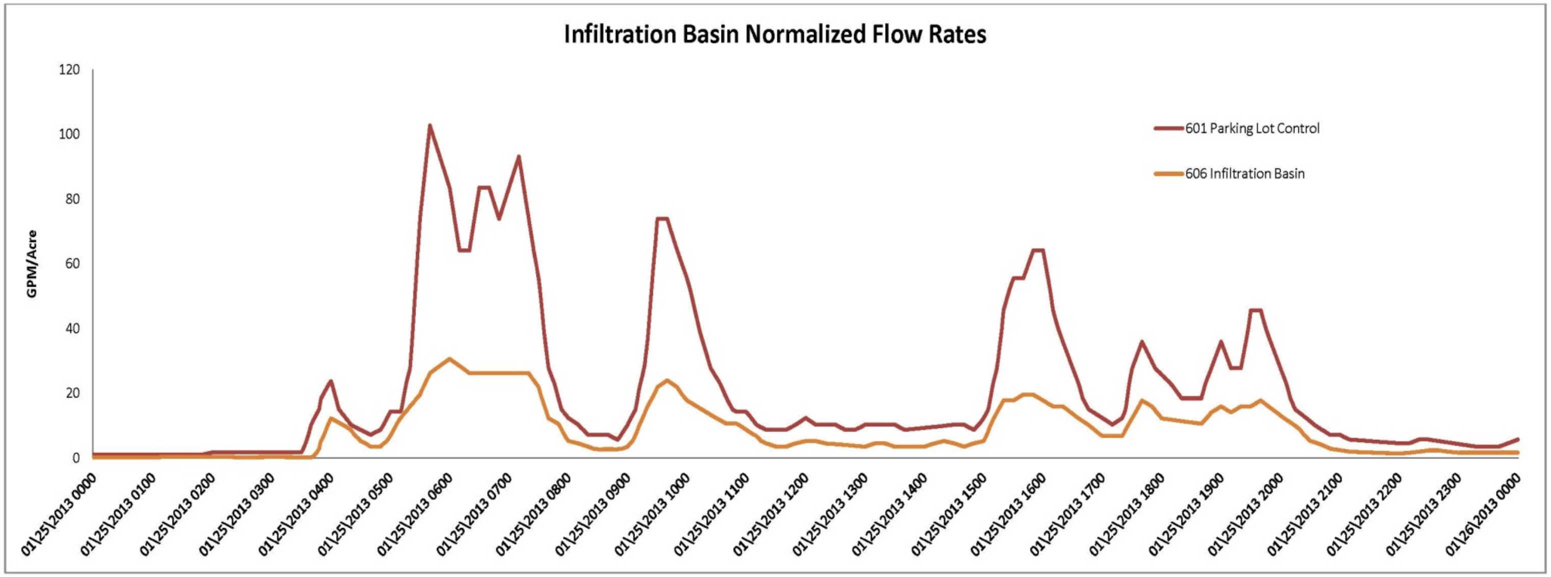
† Flow meter read zero when water still flowing 4 days estimated at 57 gpd added to measured gallons (904.5 +228 =1132.5)



12-13 01/25/13 Sampled Storm Event Pavement Control vs. Infiltration Basin BMP

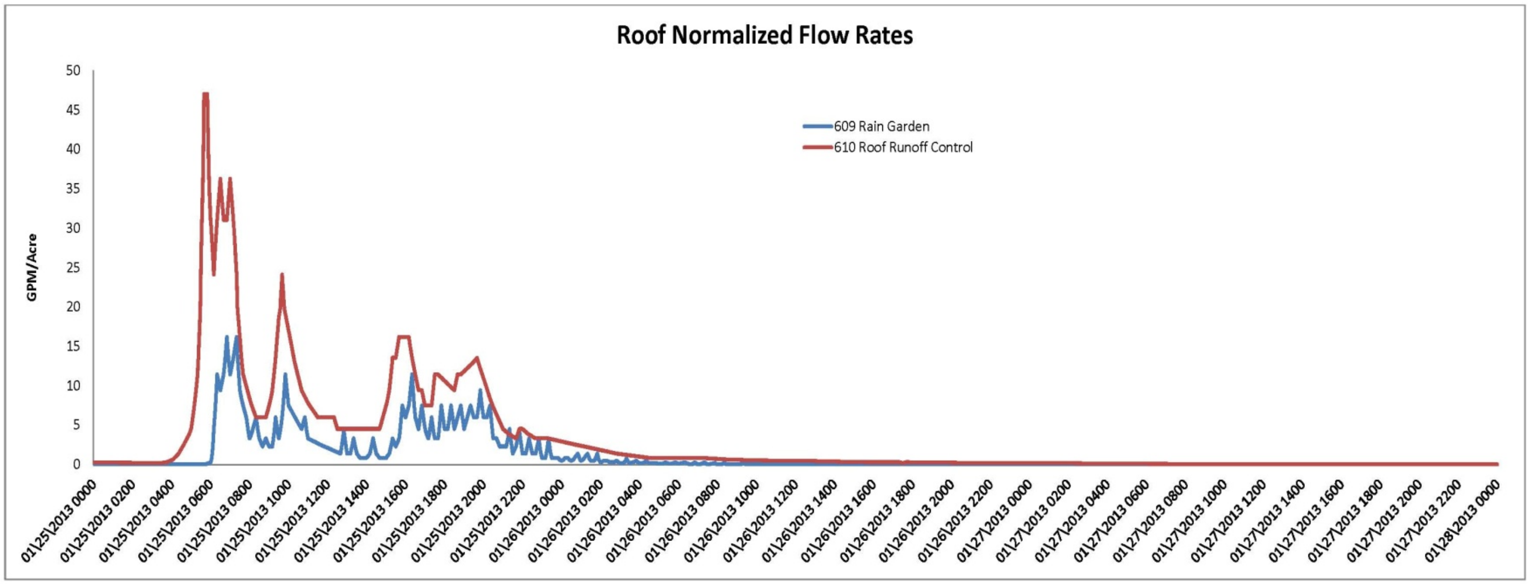
Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes	Flow ended (Date Time)
601	Parking lot Control	0.52	0.17	2400.44	2258.01	142.43	5.93%	03:16 1/25	03:40 1/25	24	23:50 1/26
606	Infiltration Basin Sub drain	0.52	0.89	12567.00	13960	-1393.00	(-11.08%)*		03:50 1/25	34	0940 1/30* still flowing

*Influenced by .17" of rain which fell on 1/24



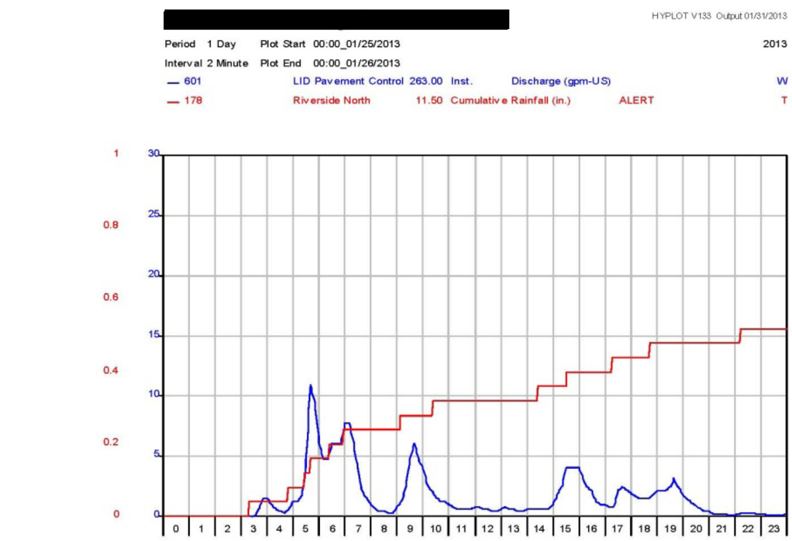
12-13 01/25/13 Sampled Storm Event Roof Control vs. Roof BMP

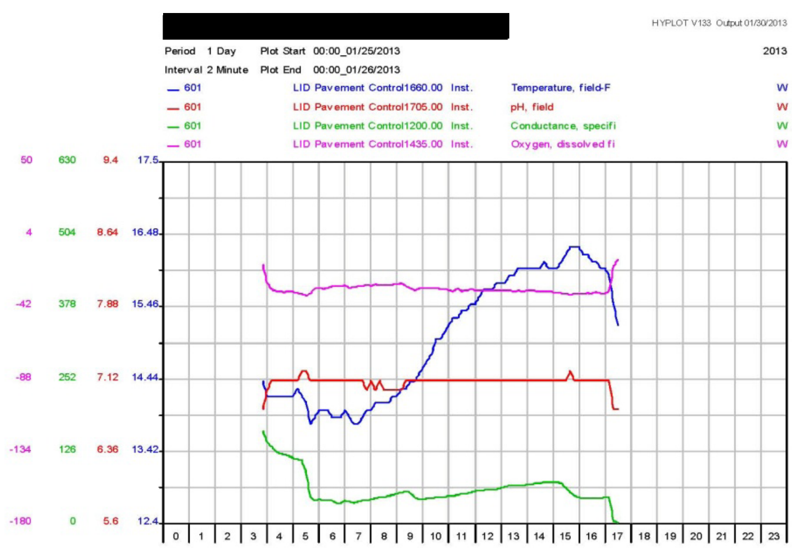
Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes	Flow ended (Date Time)
609	Rain Garden	0.52	0.13	1835.63	645.72	1189.91	64.82%	11/8/2012 17:33	05:50 1/25	2:34	09:30 1/26
610	Roof Runoff Control	0.52	0.13	1835.63	1768.29	67.34	3.67%		03:30 1/25	14	11:20 1/27

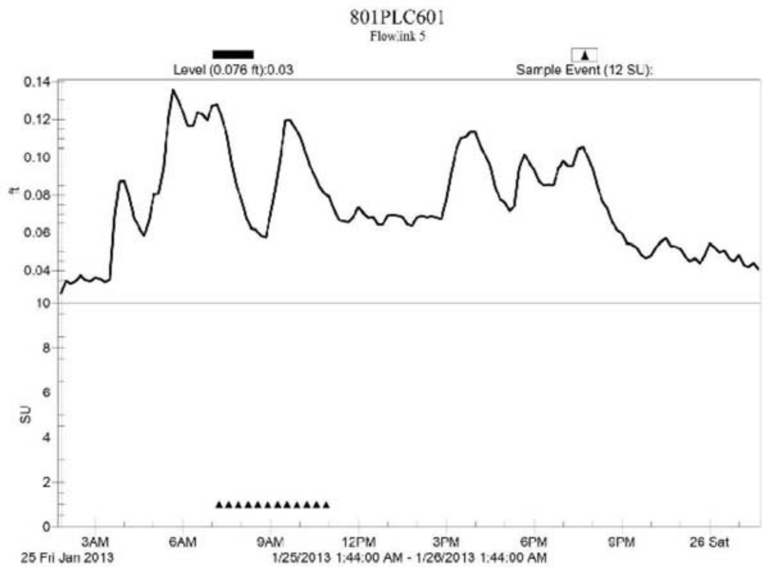


12-13 01/25/13 Sampled Storm Event -Pavement Control

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
601	Parking lot Control	0.52	0.17	2400.44	2258.01	142.43	5.93%	03:16 1/25	03:40 1/25	24	23:50 1/26






801PLC601
Flowlink 5
Level (0.076 ft):0.03
Sample Event (12 SU):
0.14
0.12
0.10
ft 0.08
0.06
0.04
10
8
6
SU
4
2
0
3AM
6AM
9AM
12PM
3PM
6PM
9PM
26 Sat
25 Fri Jan 2013
1/25/2013 1:44:00 AM - 1/26/2013 1:44:00 AM

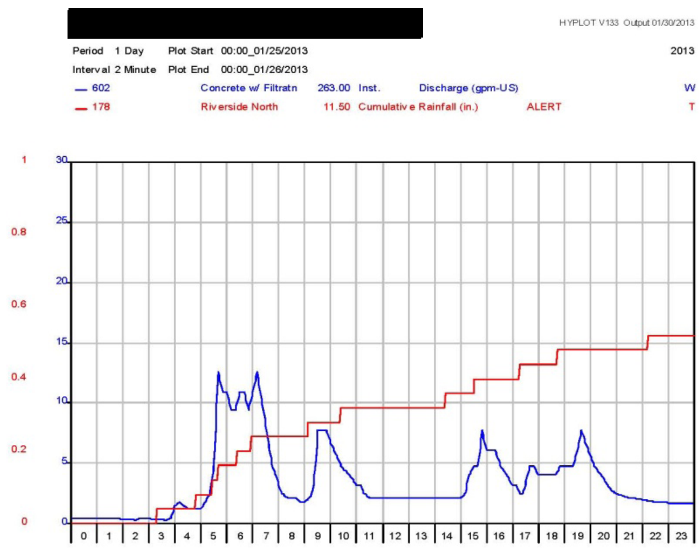

601 - Pavement Control
01/25/2013 13:04

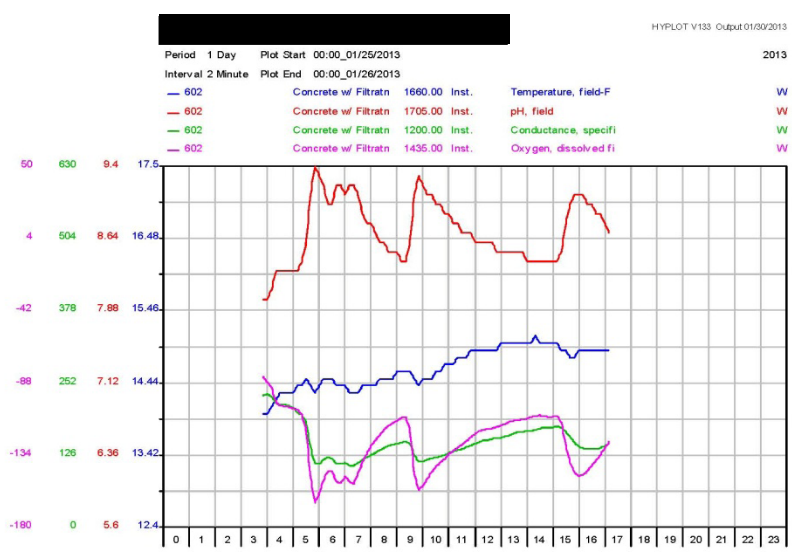
12-13 01/25/13 Sampled Storm Event –Concrete with Filter

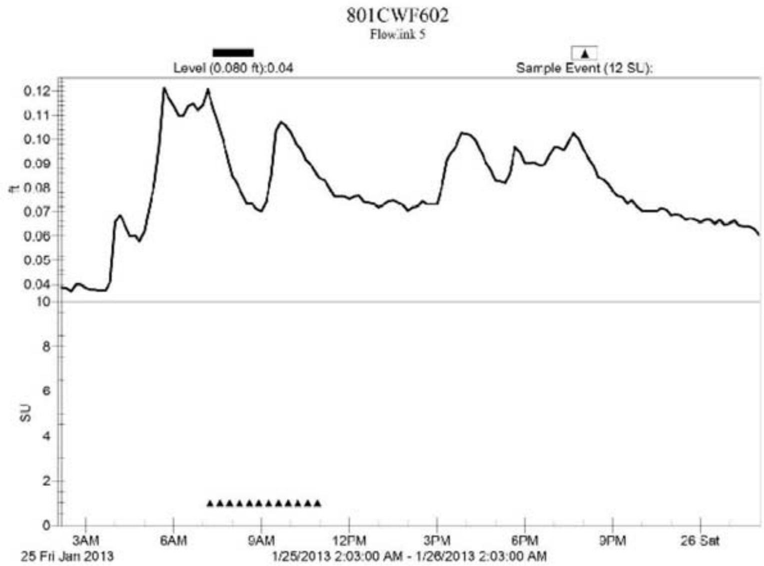
Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
602	Porous Concrete with filter	0.52	0.22	3106.45	5555	-2448.55	(-78.82%)*	03:16 1/25	03:50 1/25	34	12:00 1/26**

*Influenced by .17" of rain which fell on 1/24 and base flow from irrigation system

**Approximate time base flow reached



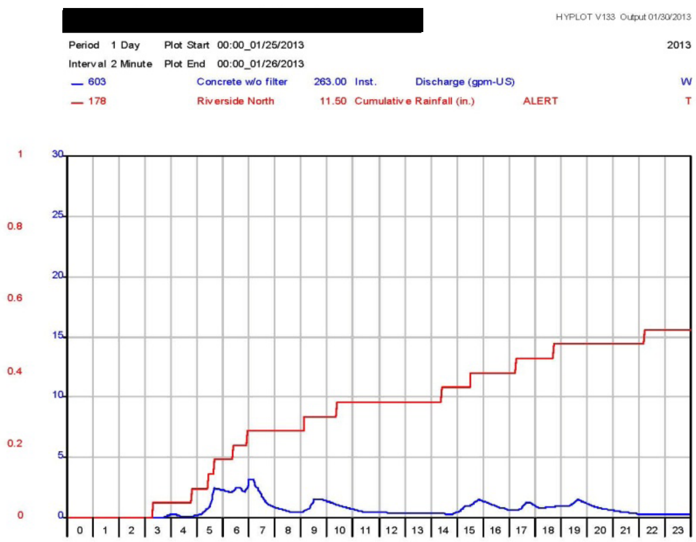



801CWF602
Flowlink 5
Level (0.080 ft):0.04
Sample Event (12 SL):
0.12
0.11
0.10
0.09
ft 0.08
0.07
0.06
0.05
0.04
10
8
SU
6
4
2
0
3AM
6AM
9AM
12PM
3PM
6PM
9PM
26 Sat
25 Fri Jan 2013
1/25/2013 2:03:00 AM - 1/26/2013 2:03:00 AM

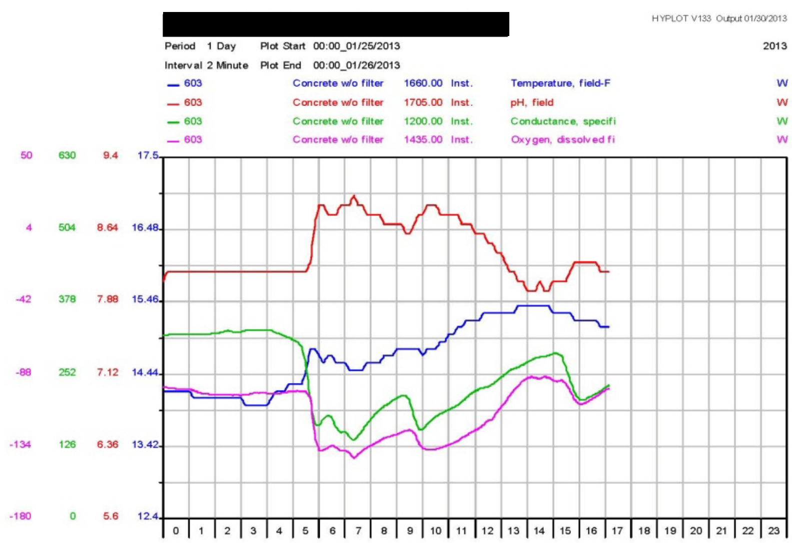

602 - Concrete w/ Filt.
01/25/2013 14:18

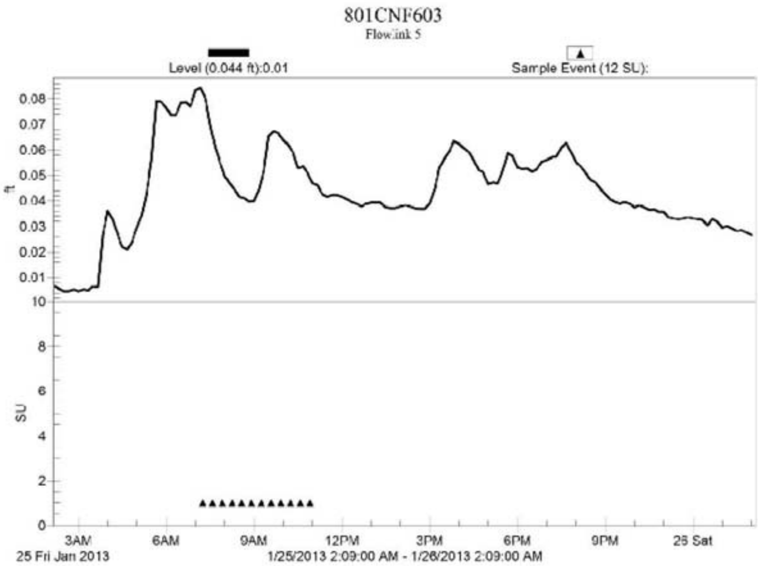
12-13 01/25/13 Sampled Storm Event –Concrete without Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
603	Porous Concrete without filter	0.52	0.23	3247.65	1229.04	2018.61	62.16%	03:16 1/25	03:30 1/25	14	10:19 1/31* still flowing



*Small storm event discharge scale ~¼ of past events

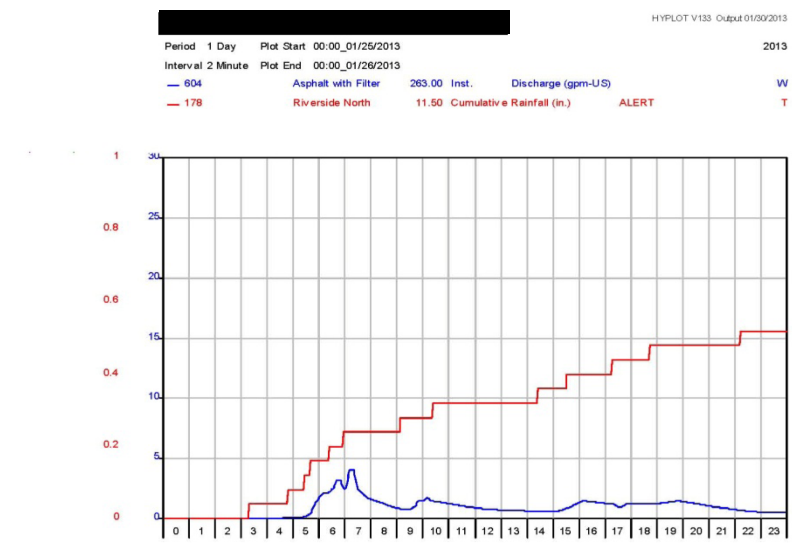



801CNF603
Flowlink 5
Level (0.044 ft):0.01
Sample Event (12 SL):
ft
SU
3AM
6AM
9AM
12PM
3PM
6PM
9PM
26 Sat
25 Fri Jan 2013
1/25/2013 2:09:00 AM - 1/26/2013 2:09:00 AM

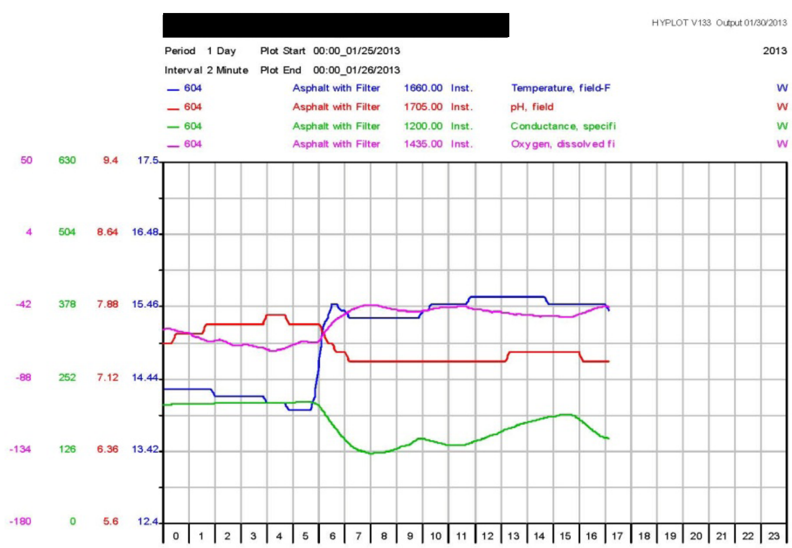

603 - Concrete no Filt
01/25/2013 14:34

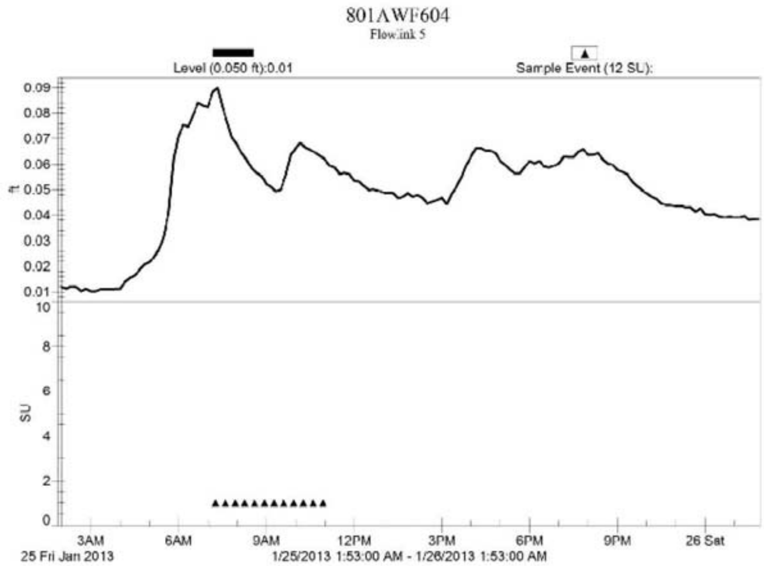
12-13 01/25/13 Sampled Storm Event –Asphalt with Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
604	Porous Asphalt with filter	0.52	0.16	2259.24	1705	554.24	24.53%	03:16 1/25	04:10 1/25	54	13:30 1/31 * still flowing



*Small storm event discharge scale ~¼ of past events





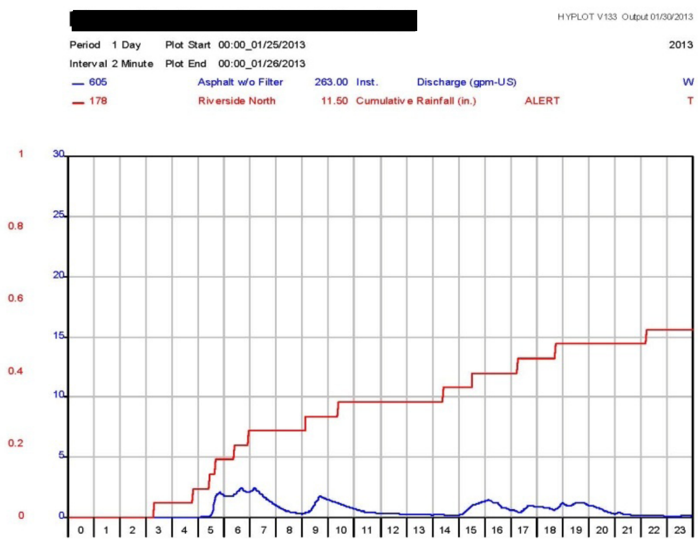
801AWF604
Flowlink 5
Level (0.050 ft):0.01
Sample Event (12 SL):
0.09
0.08
0.07
0.06
ft 0.05
0.04
0.03
0.02
0.01
10
8
6
SU
4
2
0
3AM
6AM
9AM
12PM
3PM
6PM
9PM
26 Sat
25 Fri Jan 2013
1/25/2013 1:53:00 AM - 1/26/2013 1:53:00 AM

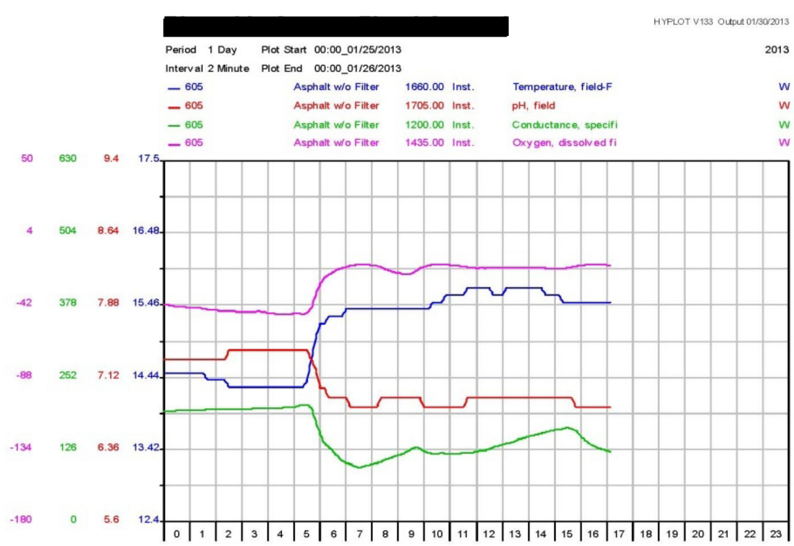
604- Asphalt w/ Filt.
01/25/2013 14:49

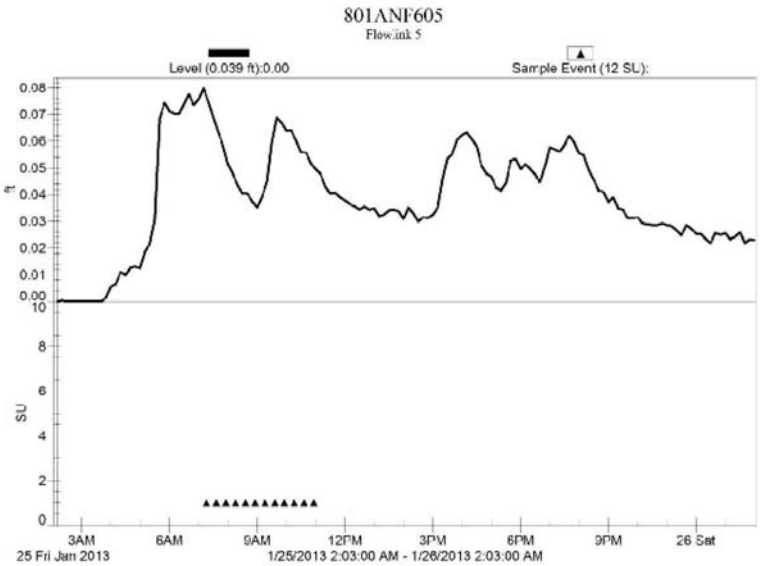
12-13 01/25/13 Sampled Storm Event –Asphalt without Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
605	Porous Asphalt without filter	0.52	0.22	3106.45	1132.5†	1973.95	63.54%	03:16 1/25	03:50 1/25	34	13:30 1/31 * still flowing

† Flow meter read zero when water still flowing 4 days estimated at 57 gpd added to measured gallons (904.5 +228 =1132.5)







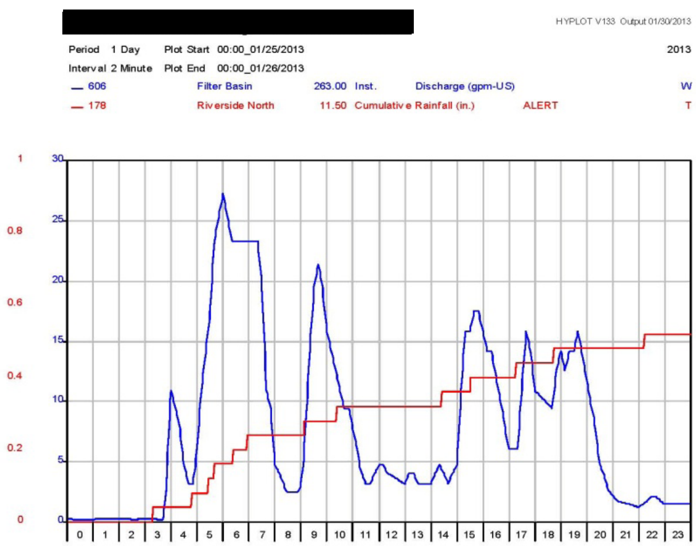
801ANF605
Flowlink 5
Level (0.039 ft):0.00
Sample Event (12 SL):
0.08
0.07
0.06
0.05
ft 0.04
0.03
0.02
0.01
0.00
10
8
SU 6
4
2
0
3AM
6AM
9AM
12PM
3PM
6PM
9PM
26 Sat
25 Fri Jan 2013
1/25/2013 2:03:00 AM - 1/26/2013 2:03:00 AM

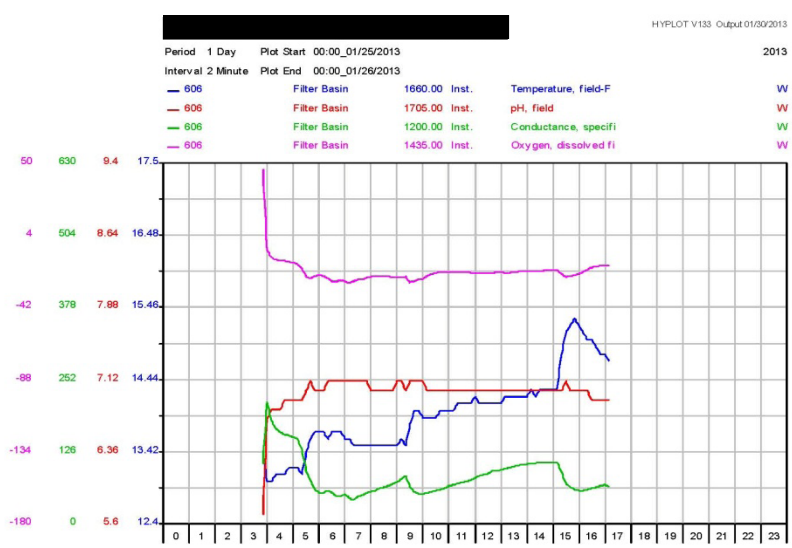
605 - Asphalt no Filt.
01/25/2013 15:00

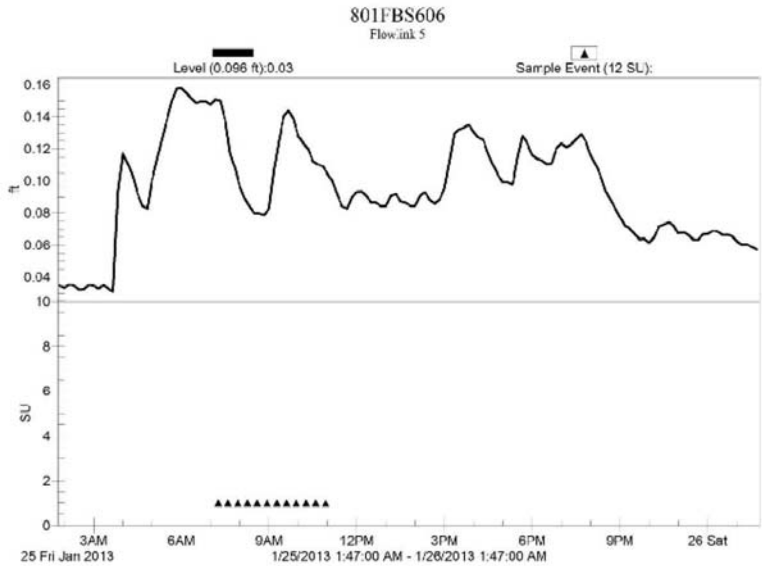
12-13 01/25/13 Sampled Storm Event –Infiltration Basin

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
606	Infiltration Basin Sub drain	.52	0.89	12567.00	13960	-1393.00	(-11.08%)*	03:16 1/25	03:50 1/25	34	0940 1/30* still flowing

*Influenced by .17" of rain which fell on 1/24






801FBS606
Flowlink 5
Level (0.096 ft):0.03
Sample Event (12 SL):
ft
SU
3AM
6AM
9AM
12PM
3PM
6PM
9PM
26 Sat
25 Fri Jan 2013
1/25/2013 1:47:00 AM - 1/26/2013 1:47:00 AM


606- Filter Basin
01/25/2013 15:14

12-13 01/25/13 Sampled Storm Event –Infiltration Basin Overflow

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
607	Filtration Basin Overflow	0.52	0.89	12567.00	--	--	--	03:16 1/25	--	--	--

*Not enough rain to overwhelm the infiltration basin therefore no water observed in overflow channel

*No water to submerge sonde, no accurate field parameter readings

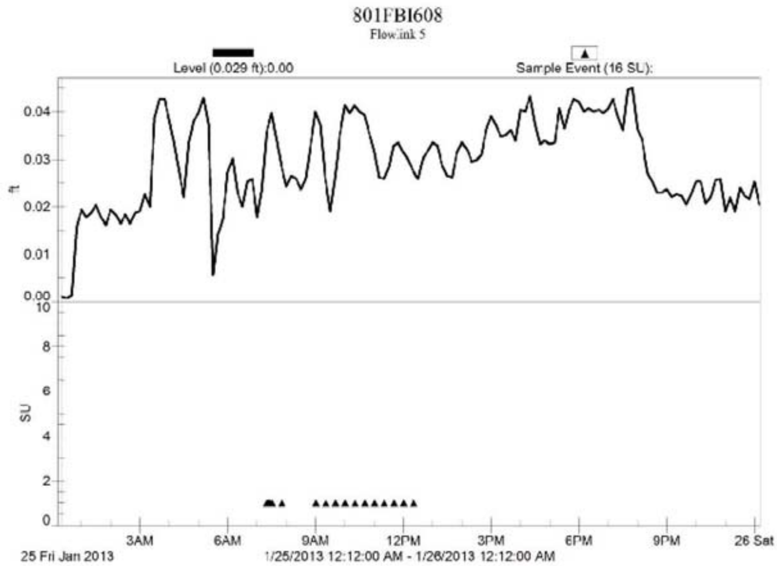
12-13 01/25/13 Sampled Storm Event –Infiltration Basin Influent

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
608	Filtration Basin Influent	0.52	0.89	12567.00	--	--	--	03:16 1/25	--	--	--

*Due to Construction plan changes, no accurate flow measurements recorded

*Due to construction changes in sampling vault, flow measurements are not accurate and should not be used for analysis

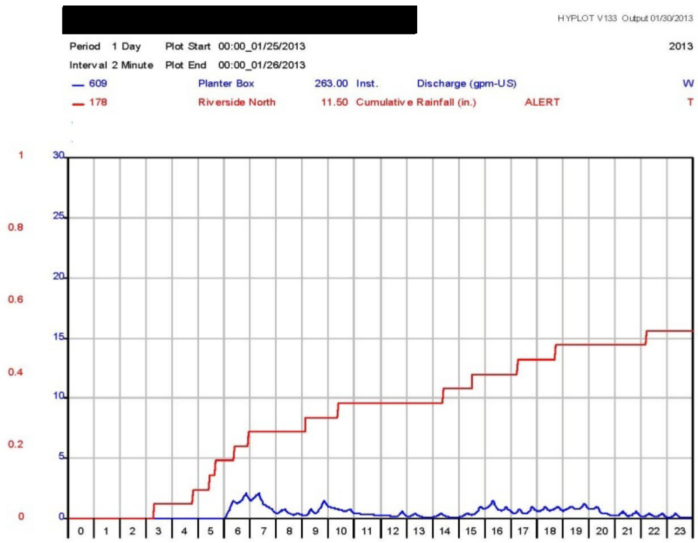
*Not enough water to submerge sonde, no accurate field parameter readings

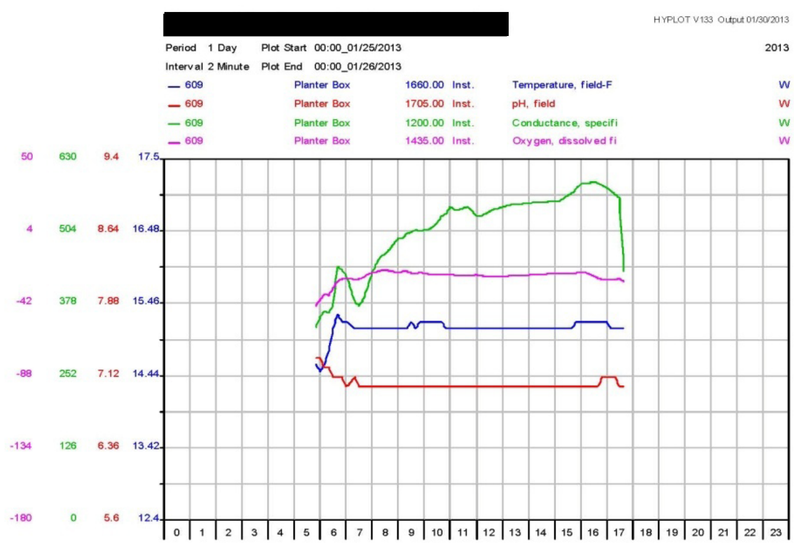


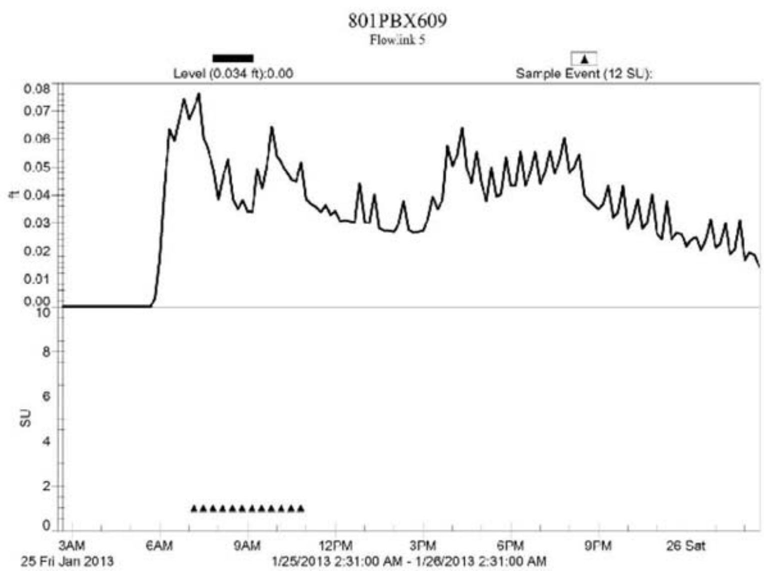
*Note first few sample markers are false as sampler had distributor arm error and could not take a sample. Fixed distributor arm and began sampling program at 0751. Rain stopped and not enough liquid to sample so stopped program at 0810. Rain began again and resumed program at 0901. Samples 9B, 10B, and 12B not collected due to not enough liquid in sample well.

12-13 01/25/13 Sampled Storm Event –Rain Garden

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
609	Rain Garden	0.52	0.13	1835.63	645.72	1189.91	64.82%	03:16 1/25	05:50 1/25	2:34	09:30 1/26



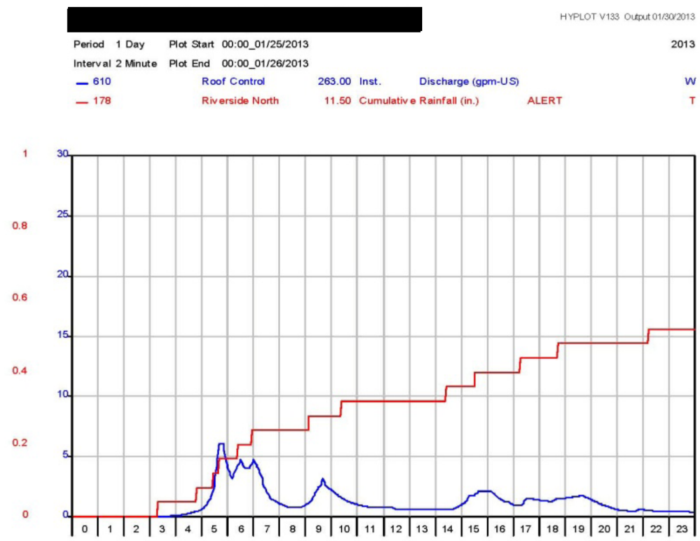


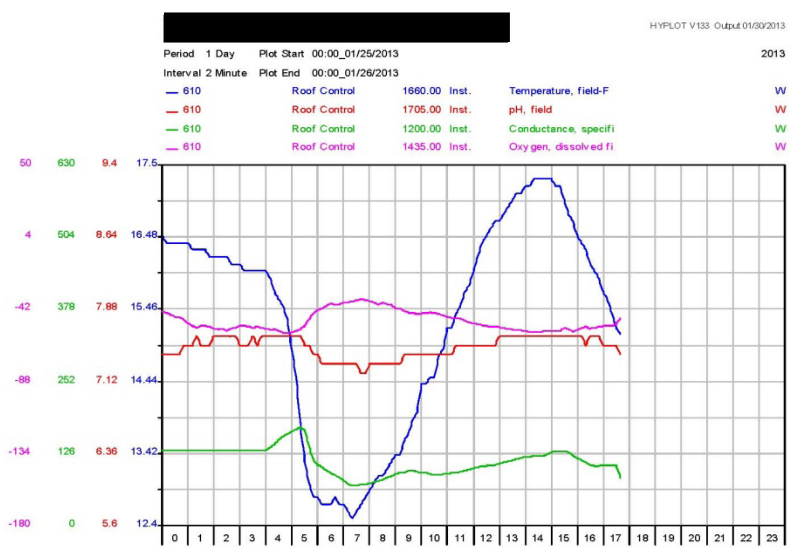


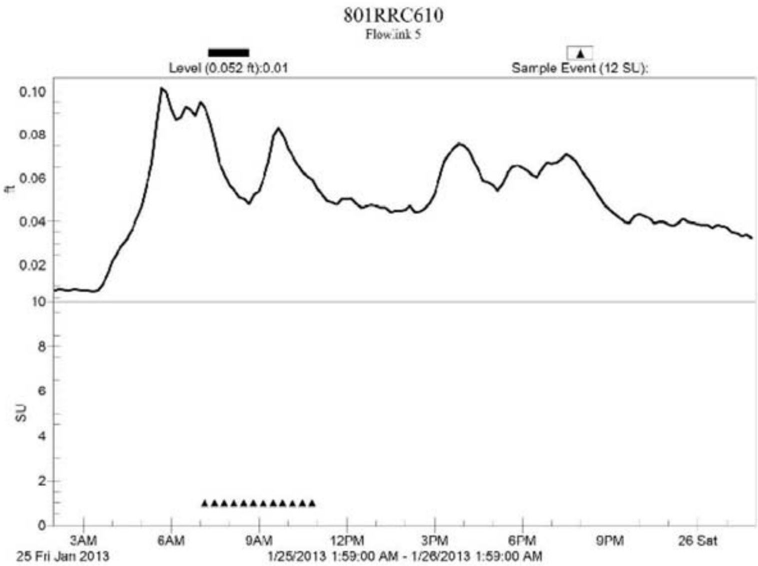
Note: Samples 4A, 4B, 5A, and 5B not collected due to suck tube becoming unsecured and rising above water level. Suck tube was re-secured and the rest of the samples were collected.

12-13 01/25/13 Sampled Storm Event –Roof Runoff Control

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (Min)	Flow ended (Date Time)
610	Roof Runoff Control	0.52	0.13	1835.63	1768.29	67.34	3.67%	03:16 1/25	03:30 1/25	14	11:20 1/27

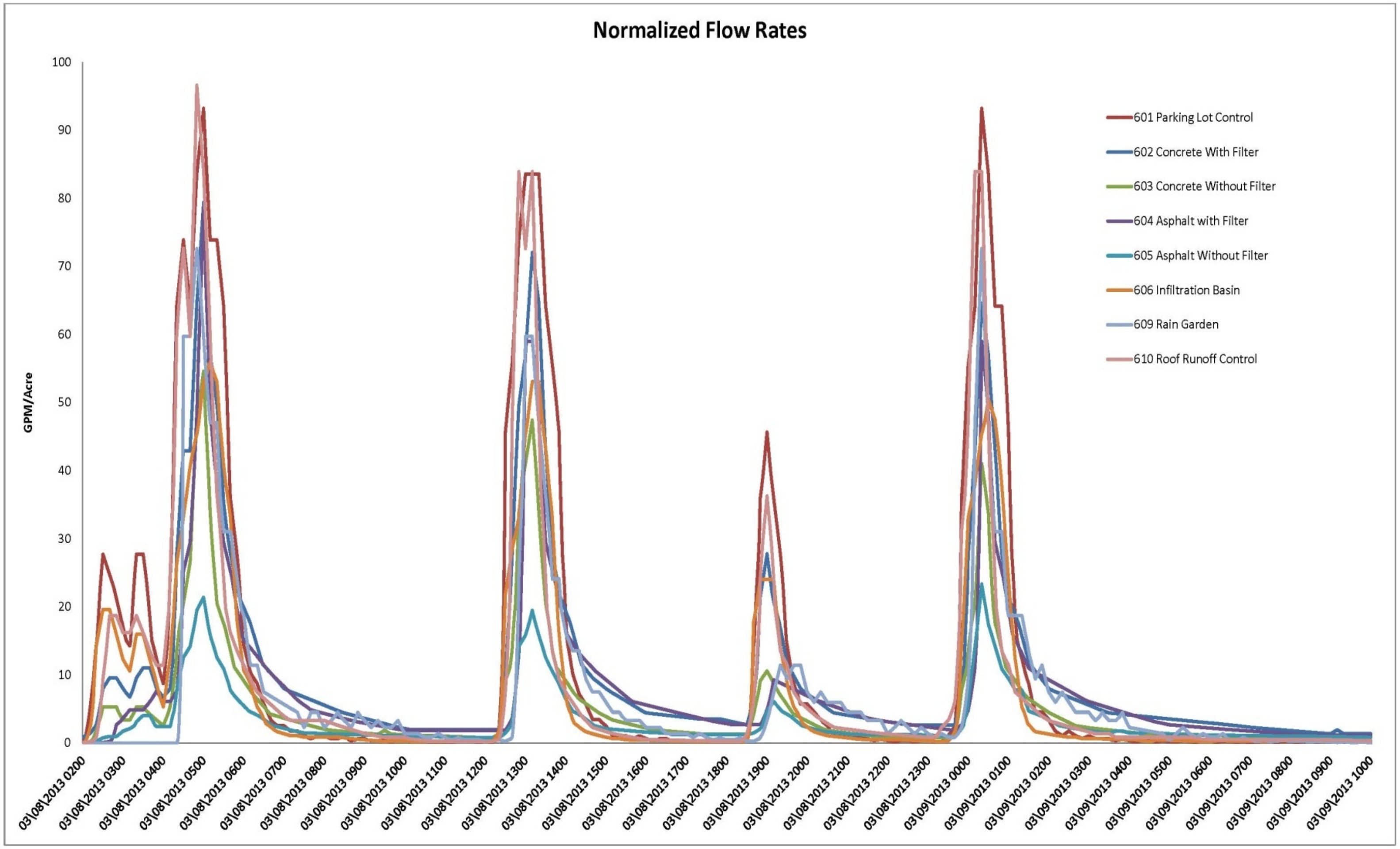





801RRC610
Flowlink 5
Level (0.052 ft):0.01
Sample Event (12 SL):
0.10
0.08
0.06
0.04
0.02
ft
10
8
6
4
2
0
SU
3AM
6AM
9AM
12PM
3PM
6PM
9PM
26 Sat
25 Fri Jan 2013
1/25/2013 1:59:00 AM - 1/26/2013 1:59:00 AM


610 Roof Runoff Control
01/25/2013 12:24

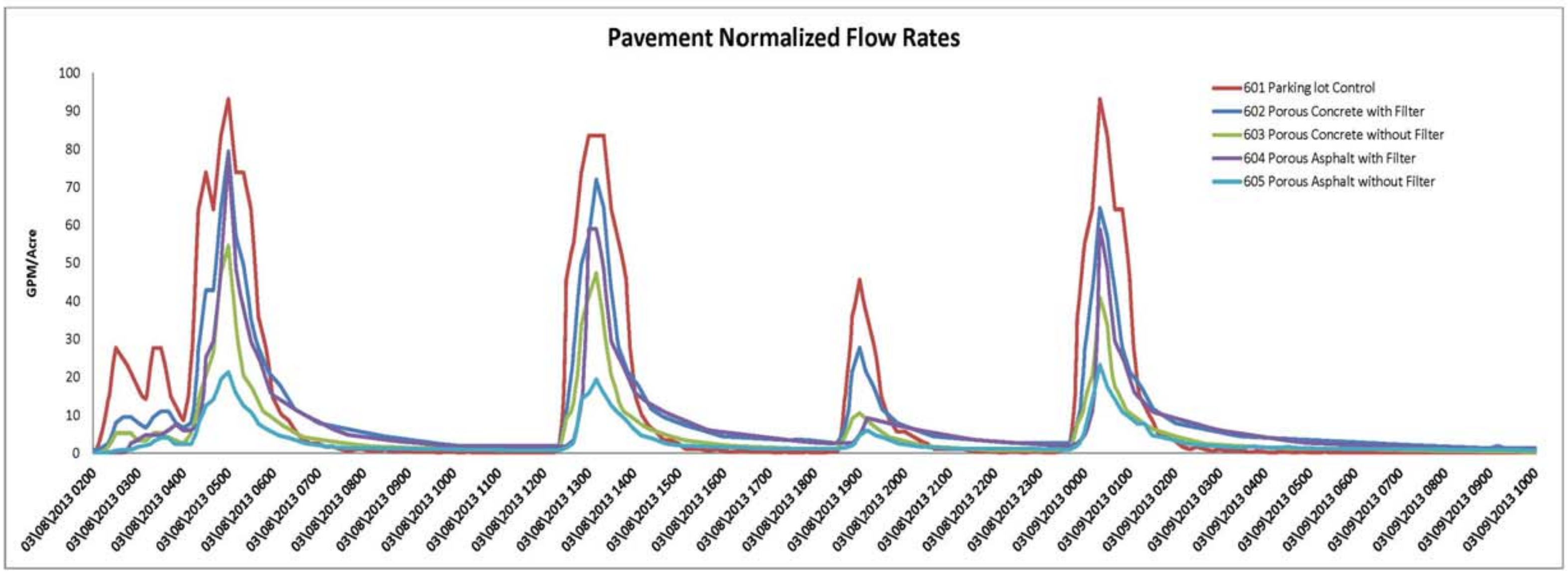
12-13 03/08/13 Storm Event



12-13 03/08/13 Storm Event Pavement Control vs. Pavement BMP's

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes	Flow ended (Date Time)
601	Parking lot Control	0.86	0.17	3969.95	4094.9	-124.95	(-3.15%)	01:35 3/08	02:00 3/08	25	7:40 3/10/13 **
602	Porous Concrete with filter	0.86	0.22	5137.59	4898.4	239.19	4.66%	01:35 3/08	02:00 3/08	25	still flowing as of 3/11/13 9:30
603	Porous Concrete without filter	0.86	0.23	5371.12	2502.3	2868.82	53.41%	01:35 3/08	02:10 3/08	35	still flowing as of 3/11/13 9:30
604	Porous Asphalt with filter	0.86	0.16	3736.43	2677.7	1058.73	28.34%	01:35 3/08	02:40 3/08	65	still flowing as of 3/11/13 9:30
605**	Porous Asphalt without filter	0.86	0.22	5137.59	7782.7	-2645.11	(-51.49%)	01:35 3/08	02:20 3/08	45	still flowing as of 3/11/13 9:30

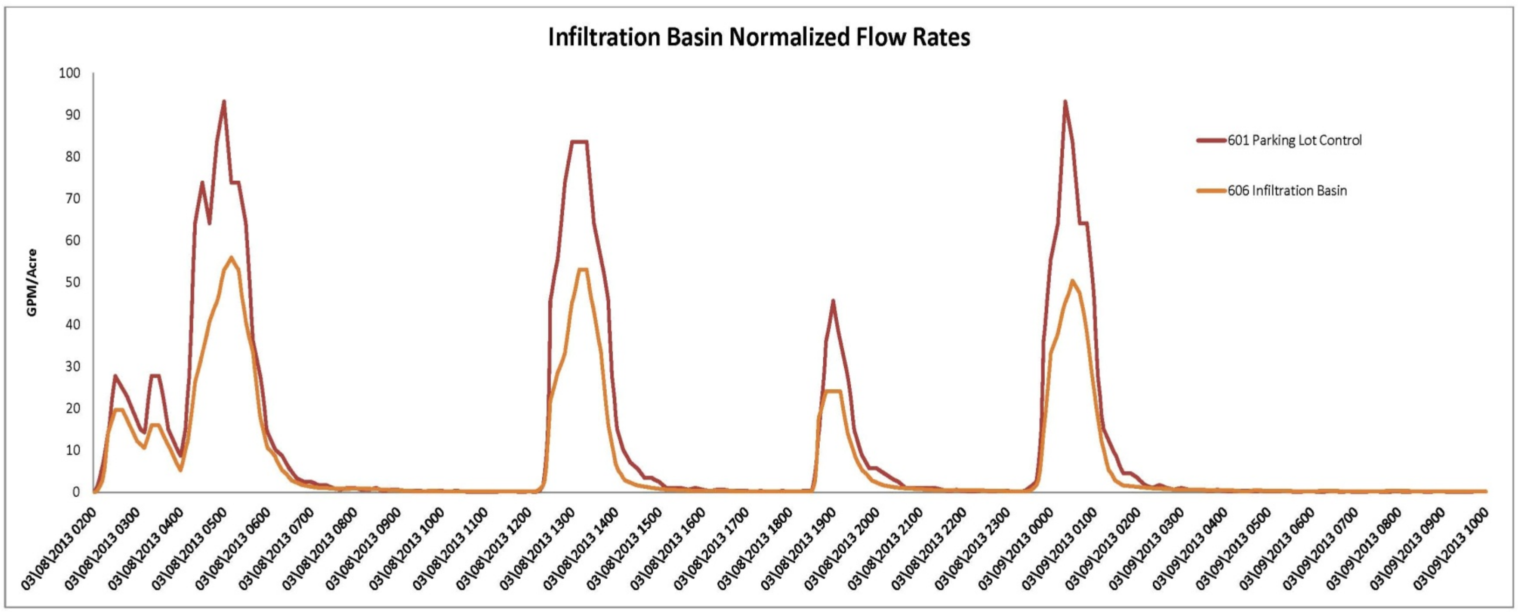
*0.1" of rain fell on 3/7 influencing BMP's especially lag time of 602
** Approximate time due to probable leaf interference
**Still looking into possibilities of why 605 measured twice as much as expected. All equipment seems in working condition; possibly watershed boundary was overrun.



12-13 03/08/13 Storm Event Pavement Control vs. Infiltration Basin BMP

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes	Flow ended (Date Time)
601	Parking lot Control	0.86	0.17	3969.95	4094.9	-124.95	-3.15%	01:35 3/08	02:00 3/08	25	7:40 3/10/13 **
606	Infiltration Basin Sub drain	0.86	0.89	20783.88	13016.5	7767.38	37.37%		02:10 3/08	35	still flowing as of 3/11/13 9:30

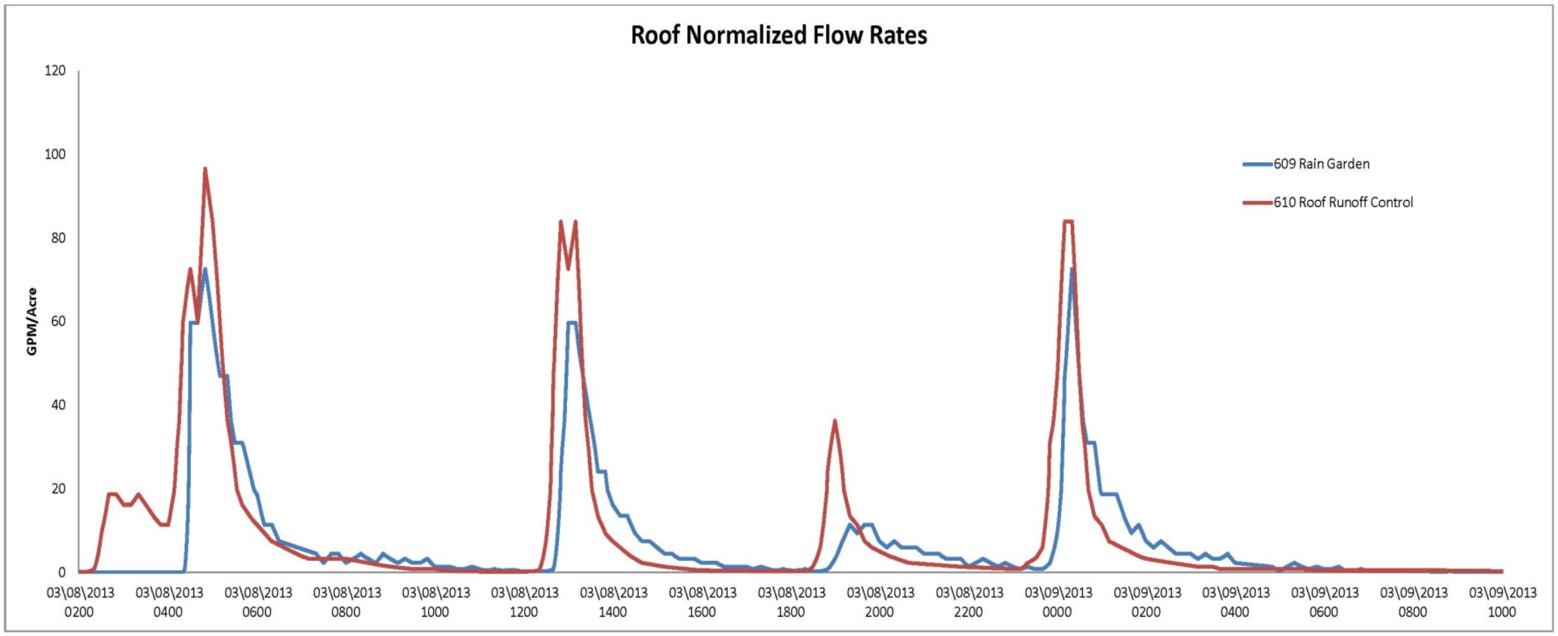
*0.1" of rain fell on 3/7 influencing BMP's especially lag time of 606
** Approximate time due to probable leaf interference



12-13 03/08/13 Storm Event Roof Control vs. Roof BMP

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (minutes	Flow ended (Date Time)
609	Rain Garden	0.86	0.13	3035.85	1918.5	1117.35	36.81%	01:35 3/08	04:30 3/08	175	11:20 3/09
610	Roof Runoff Control	0.86	0.13	3035.85	2357.2	678.65	22.35%		02:00 3/08	25	09:00 3/10

*0.1" of rain fell on 3/7 influencing BMP's although no flow observed through 609 until 3/8/13

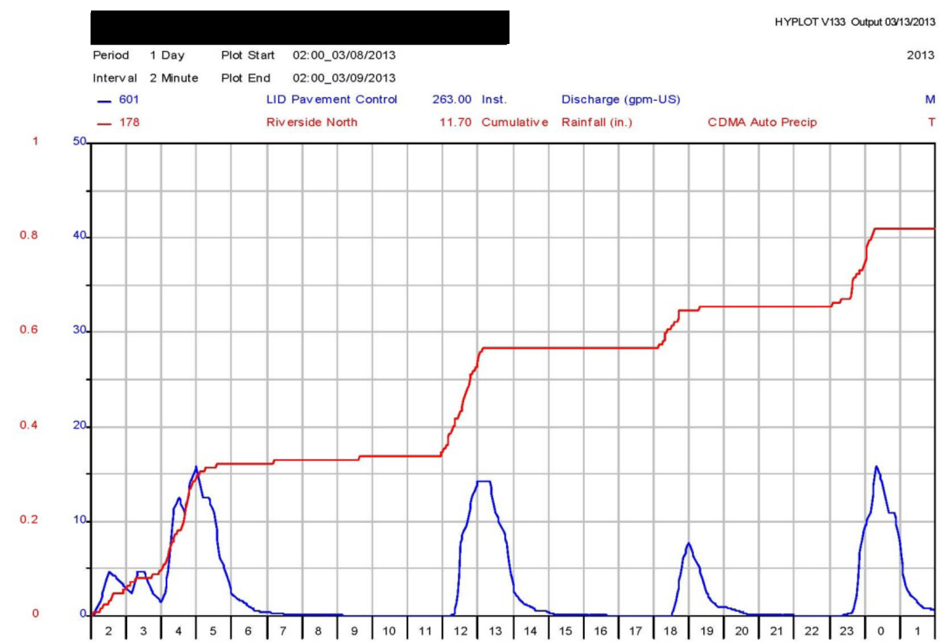


12-13 03/08/13 Storm Event -Pavement Control

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
601	Parking lot Control	0.86	0.17	3969.95	4094.9	-124.95	(-3.15%)	01:35 3/08	02:00 3/08	25	7:40 3/10/13 **

*Mathematical gains can occur when the engineered drainage area become overwhelmed and more stormwater flows into the site

** Approximate time due to probable leaf interference

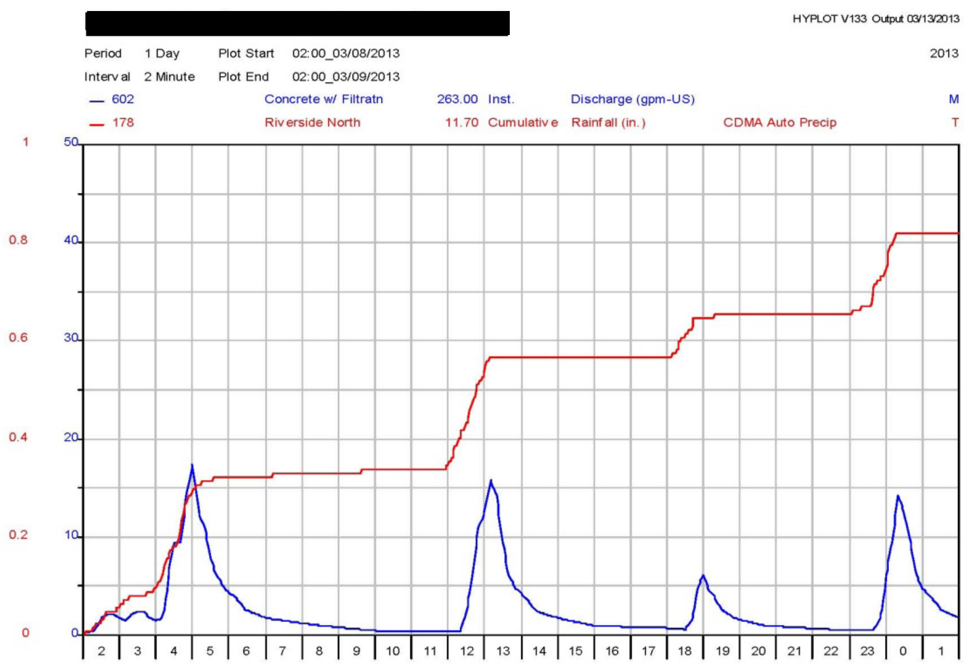


*Sonde was not deployed

12-13 03/08/13 Storm Event –Concrete with Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
602	Porous Concrete with filter	0.86	0.22	5137.59	4898.4	239.19	4.66%	01:35 3/08	02:00 3/08	25	still flowing as of 3/11/13 9:30

*0.1" of rain fell on 3/7 influencing BMP's especially lag time of 602

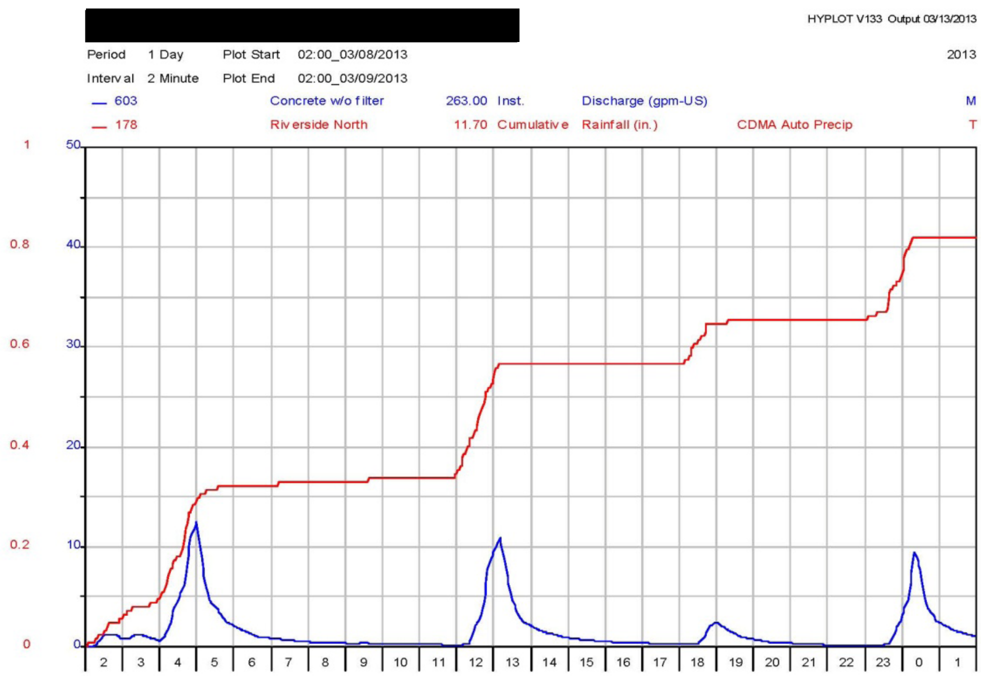


*Sonde was not deployed

12-13 03/08/13 Storm Event –Concrete without Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
603	Porous Concrete without filter	0.86	0.23	5371.12	2502.3	2868.82	53.41%	01:35 3/08	02:10 3/08	35	still flowing as of 3/11/13 9:30

*0.1" of rain fell on 3/7 influencing BMP's

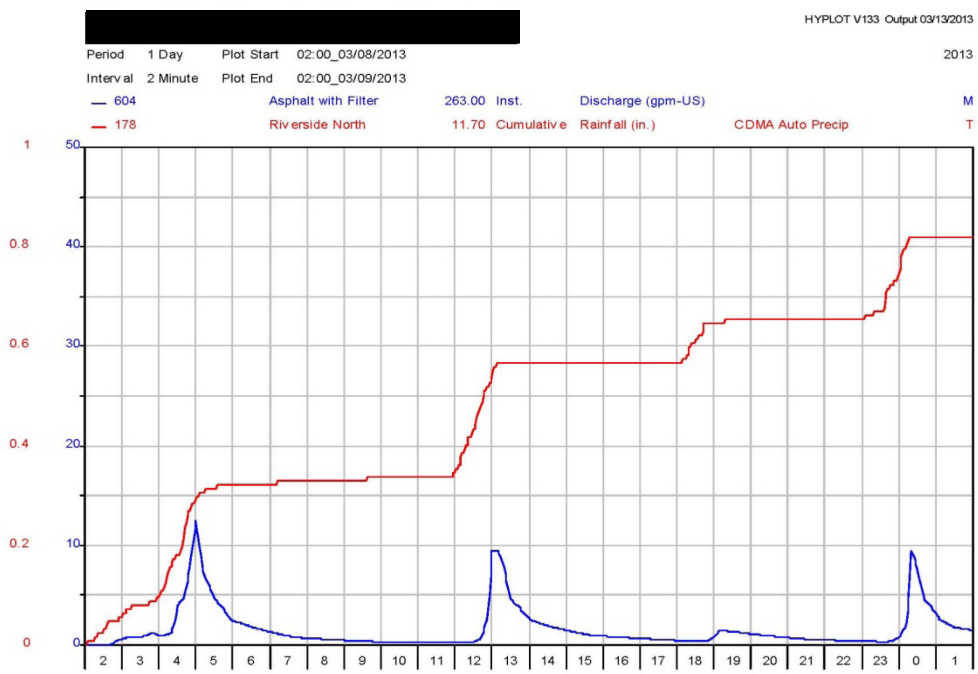


*Sonde was not deployed

12-13 03/08/13 Storm Event –Asphalt with Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
604	Porous Asphalt with filter	0.86	0.16	3736.43	2677.7	1058.73	28.34%	01:35 3/08	02:40 3/08	65	still flowing as of 3/11/13 9:30

*0.1" of rain fell on 3/7 influencing BMP's

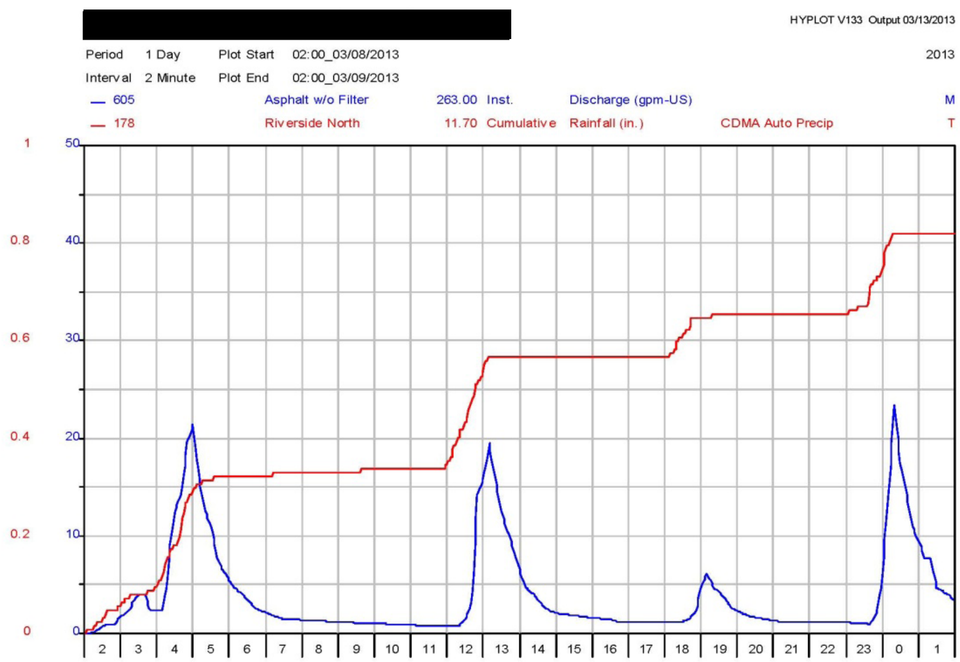


*Sonde was not deployed

12-13 03/08/13 Storm Event –Asphalt without Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
605	Porous Asphalt without filter	0.86	0.22	5137.59	7782.7	-2645.11	(-51.49%)	01:35 3/08	02:20 3/08	45	still flowing as of 3/11/13 9:30

*Mathematical gains can occur when the engineered drainage area become overwhelmed and more stormwater flows into the site
*0.1" of rain fell on 3/7 influencing BMP's

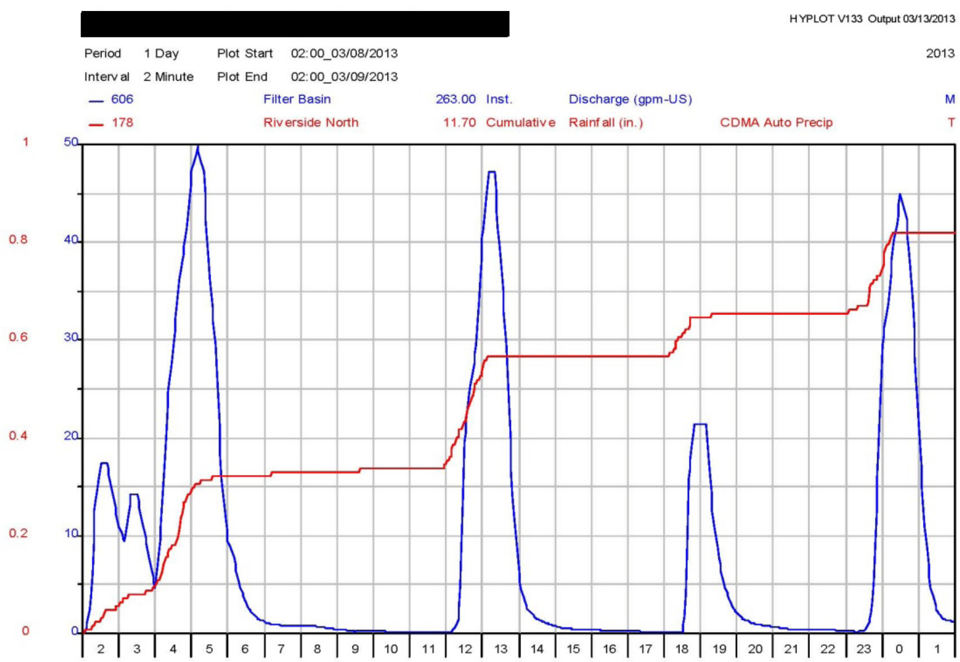


*Sonde was not deployed

12-13 03/08/13 Storm Event –Infiltration Basin

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began- Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
606	Infiltration Basin Sub drain	0.86	0.89	20783.88	13016.5	7767.38	37.37%		02:10 3/08	35	still flowing as of 3/11/13 9:30

*0.1" of rain fell on 3/7 influencing BMP's



*Sonde was not deployed

12-13 03/08/13 Storm Event –Infiltration Basin Influent

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
608	Filtration Basin Influent	0.86	0.89	20783.88	--	--	--	01:35 3/08	--	--	--

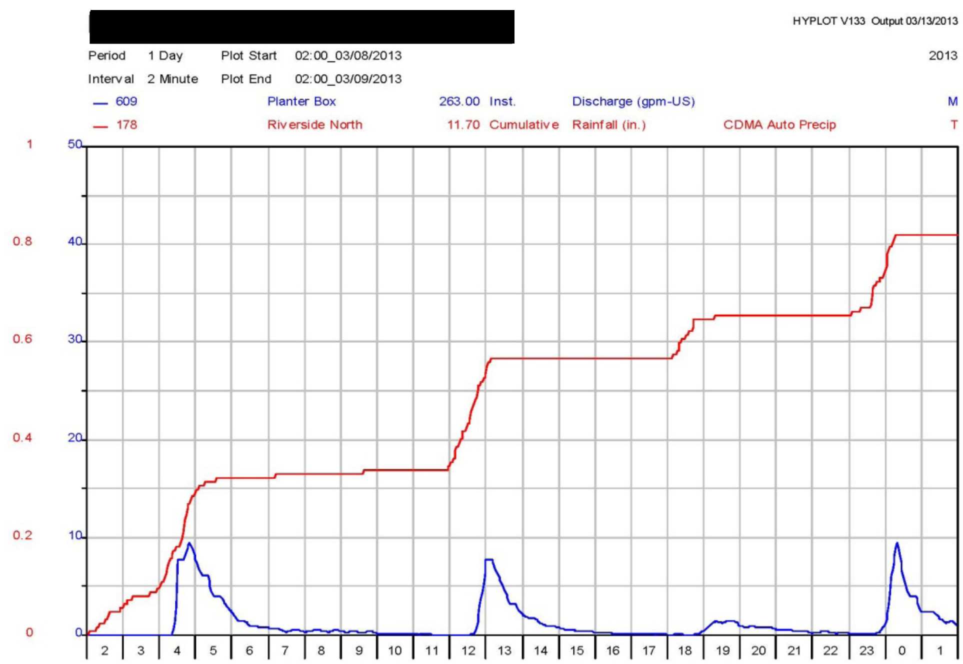
*Due to Construction plan changes, no accurate flow measurements recorded

*Due to construction changes in sampling vault, flow measurements are not accurate and should not be used for analysis

12-13 03/08/13 Storm Event –Rain Garden

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
609	Rain Garden	0.86	0.13	3035.85	1918.5	1117.35	36.81%	01:35 3/08	04:30 3/08	175	11:20 3/09

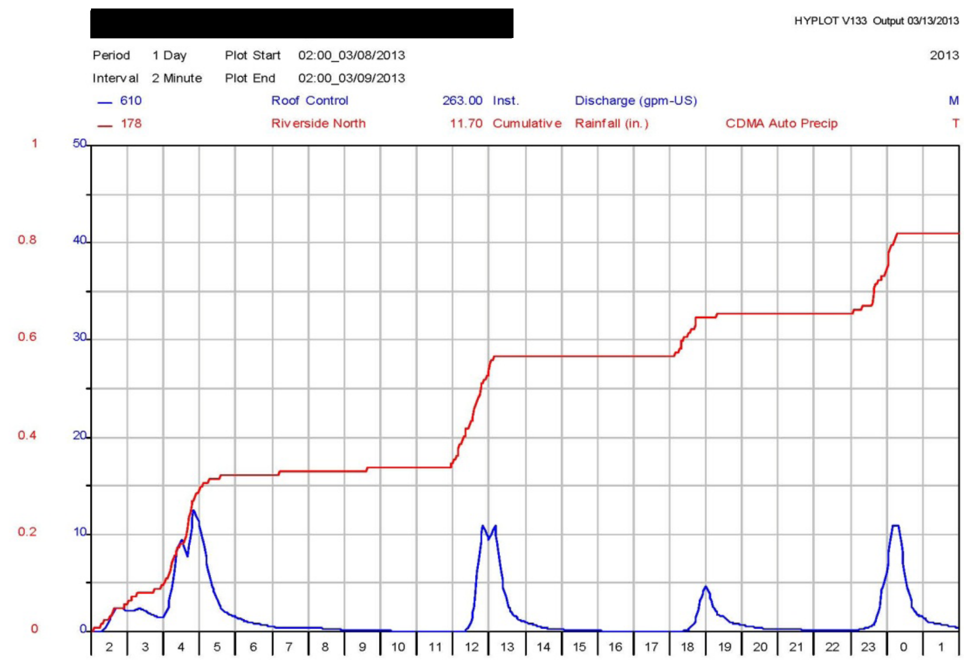
*0.1" of rain fell on 3/7 influencing BMP's



*Sonde was not deployed

12-13 03/08/13 Storm Event –Roof Runoff Control

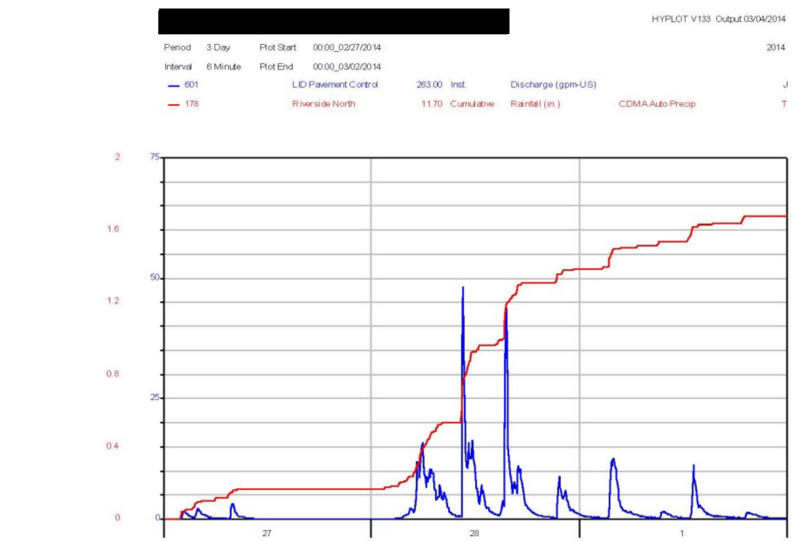
Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
610	Roof Runoff Control	0.86	0.13	3035.85	2357.2	678.65	22.35%	01:35 3/08	02:00 3/08	25	09:00 3/10

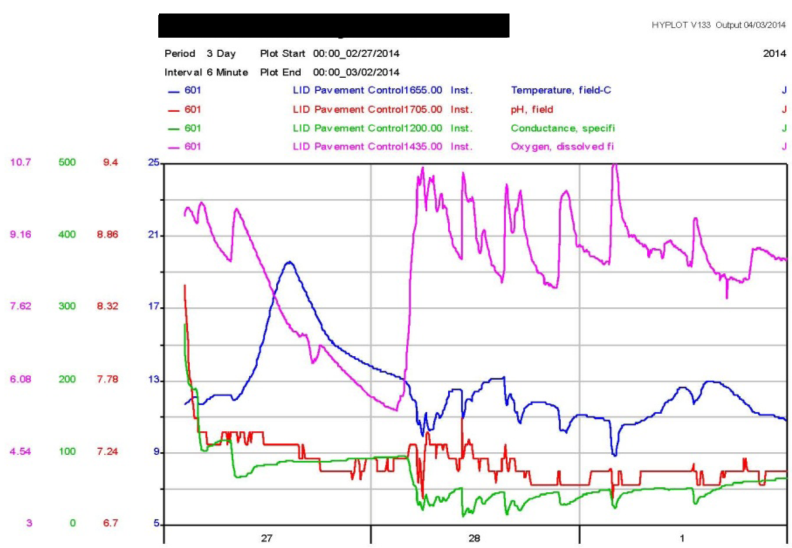


*Sonde was not deployed

13-14 02/28/14 Sampled Storm Event -Pavement Control

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
601	Parking lot Control										



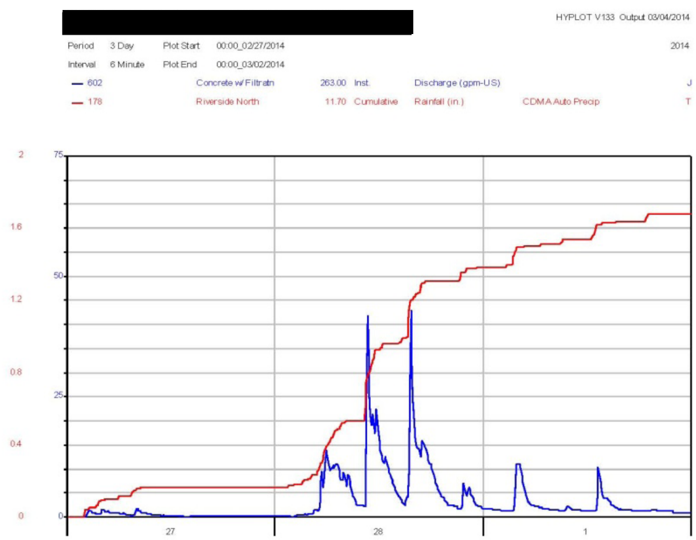


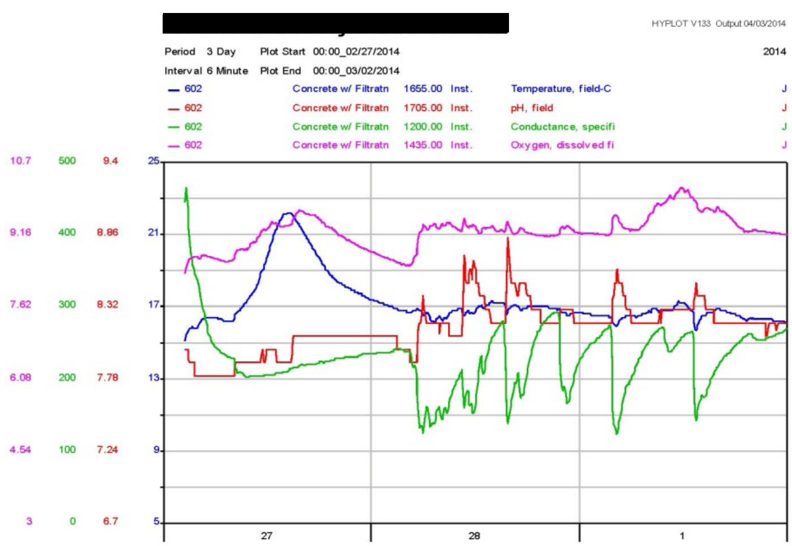
13-14 02/28/14 Sampled Storm Event –Porous Concrete with Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
602	Porous Concrete with filter										

*Influenced by .17" of rain which fell on 1/24 and base flow from irrigation system

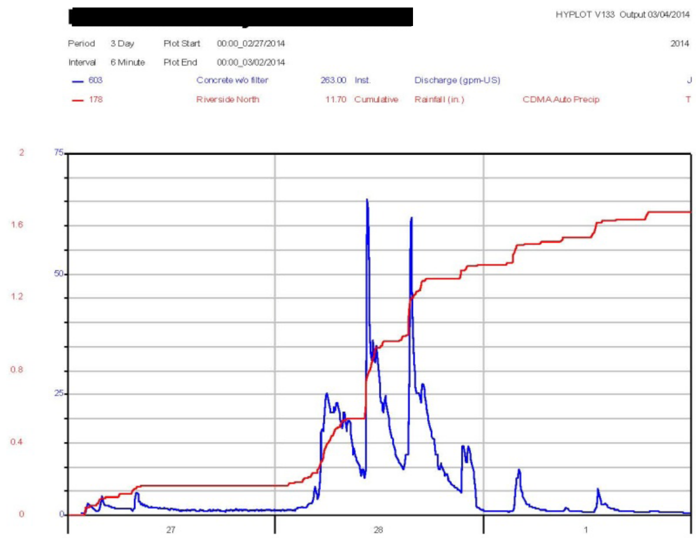
**Approximate time base flow reached

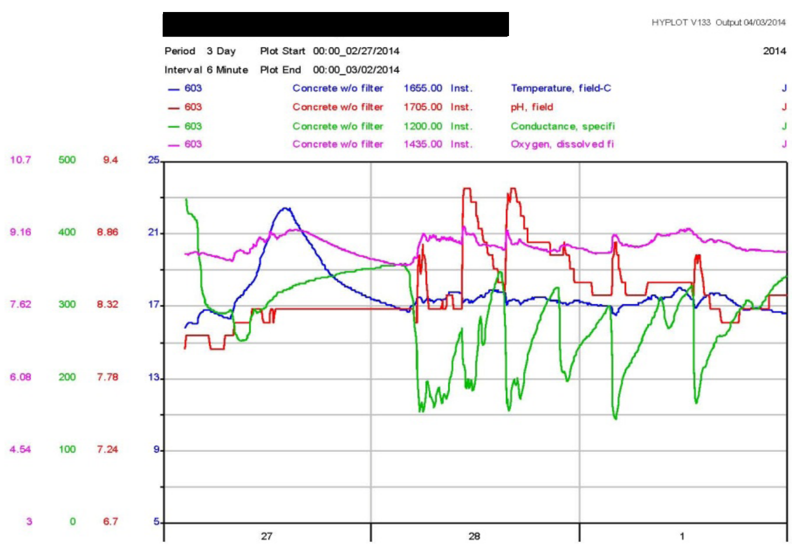




13-14 02/28/14 Sampled Storm Event – Porous Concrete without Filter

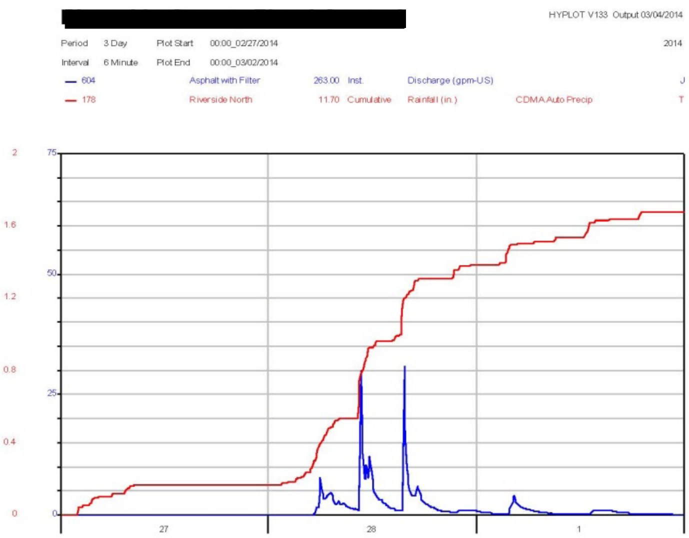
Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
603	Porous Concrete without filter										

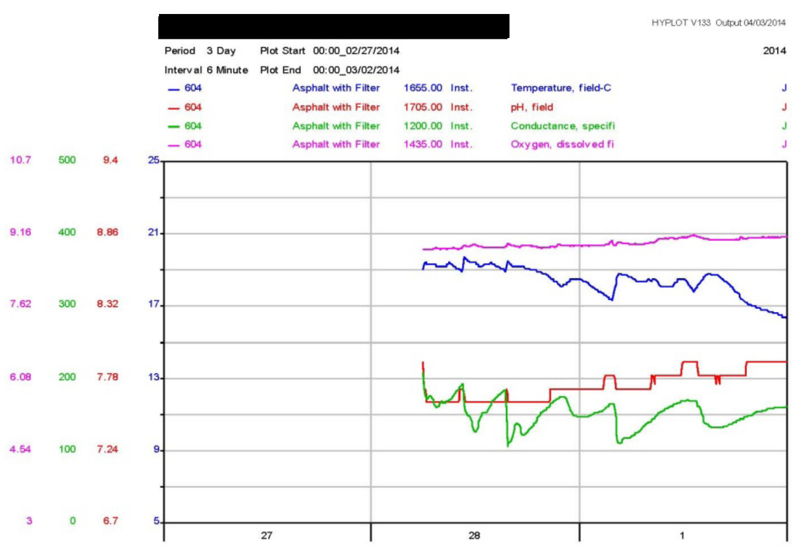




13-14 02/28/14 Sampled Storm Event – Porous Asphalt with Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
604	Porous Asphalt with filter										

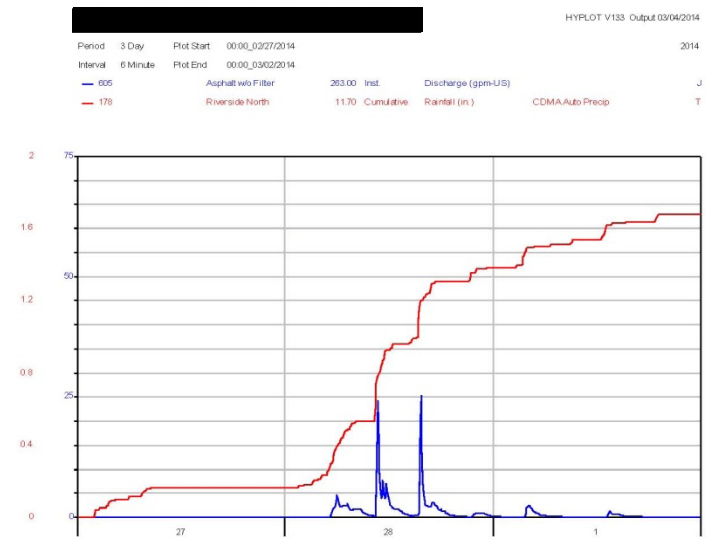


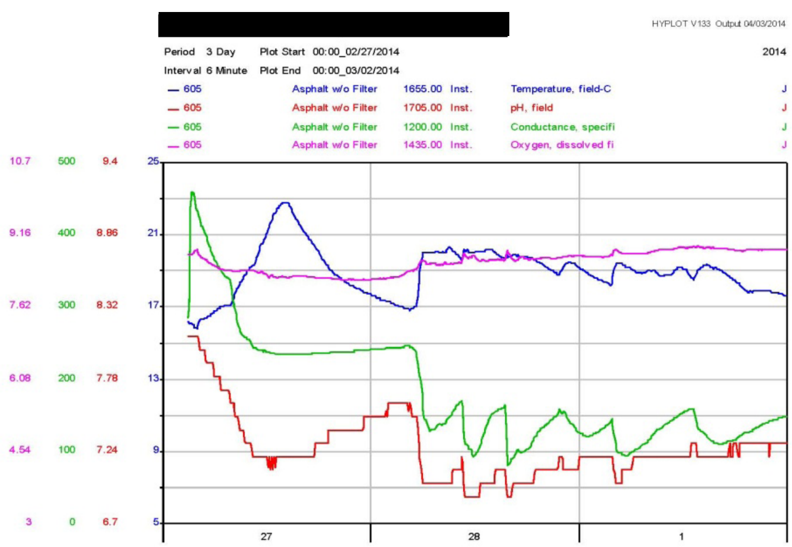


13-14 02/28/14 Sampled Storm Event – Porous Asphalt without Filter

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
605	Porous Asphalt without filter										

† Flow meter read zero when water still flowing 4 days estimated at 57 gpd added to measured gallons (904.5 +228 =1132.5)

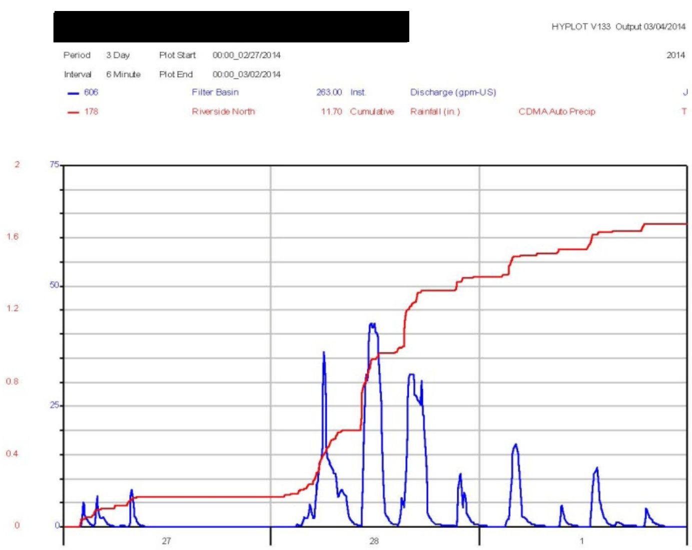


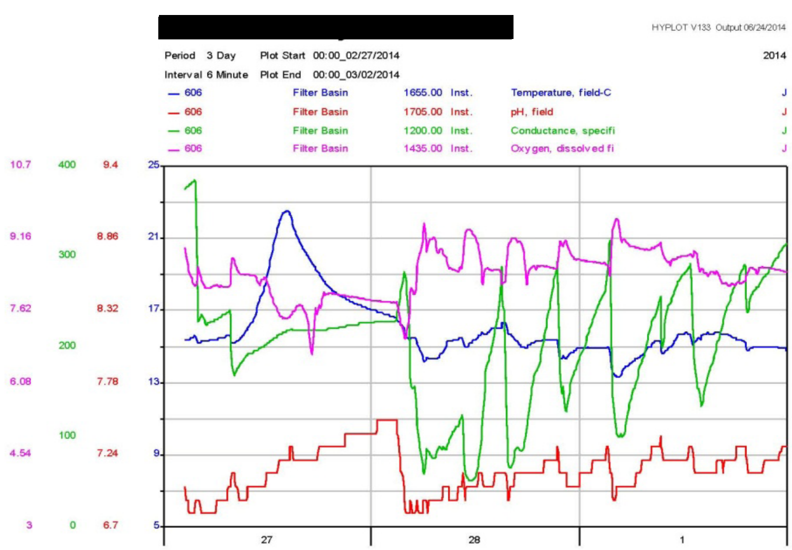


13-14 02/28/14 Sampled Storm Event –Infiltration Basin

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
606	Infiltration Basin Sub drain										

*Influenced by .17" of rain which fell on 1/24





13-14 02/28/14 Sampled Storm Event –Infiltration Basin Overflow

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
607	Filtration Basin Overflow										

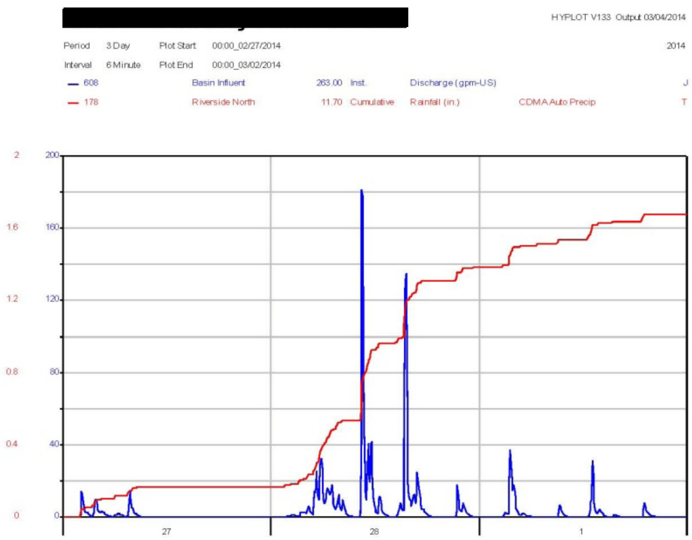
*Not enough rain to overwhelm the infiltration basin therefore no water observed in overflow channel

*No water to submerge sonde, no accurate field parameter readings

13-14 02/28/14 Sampled Storm Event –Infiltration Basin Influent

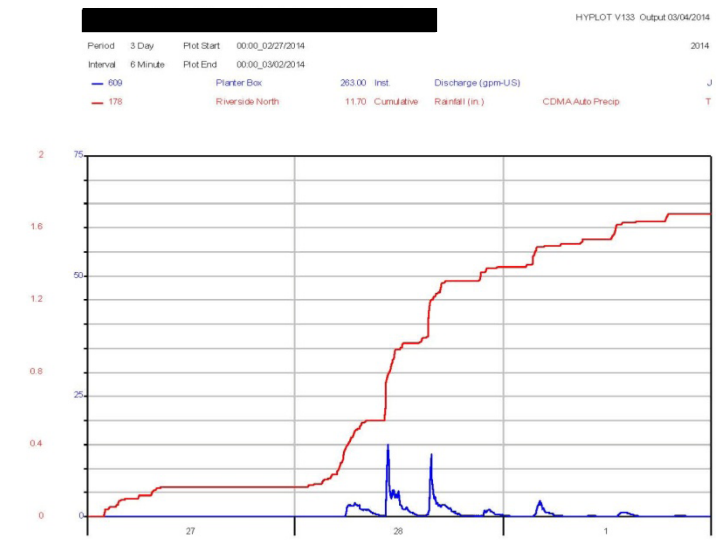
Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began- Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
608	Filtration Basin Influent										

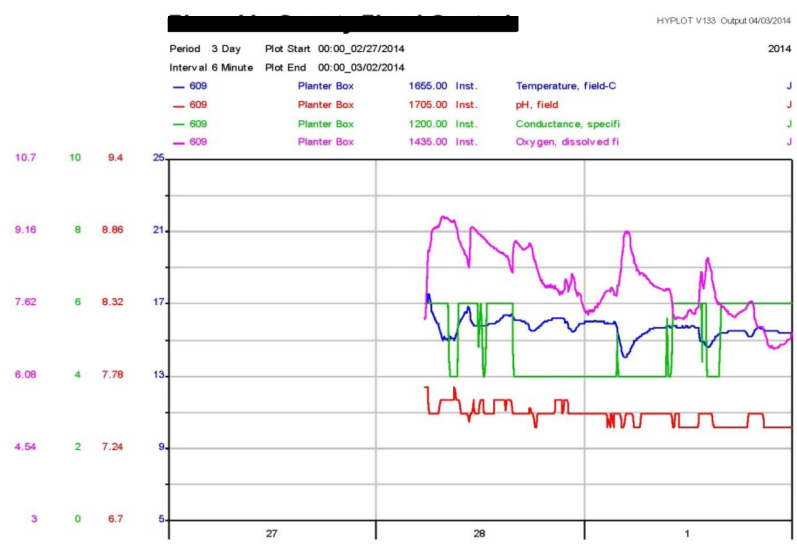
*Due to Construction plan changes, no accurate flow measurements recorded



13-14 02/28/14 Sampled Storm Event –Roof Rain Garden

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (HR: Min)	Flow ended (Date Time)
609	Rain Garden										

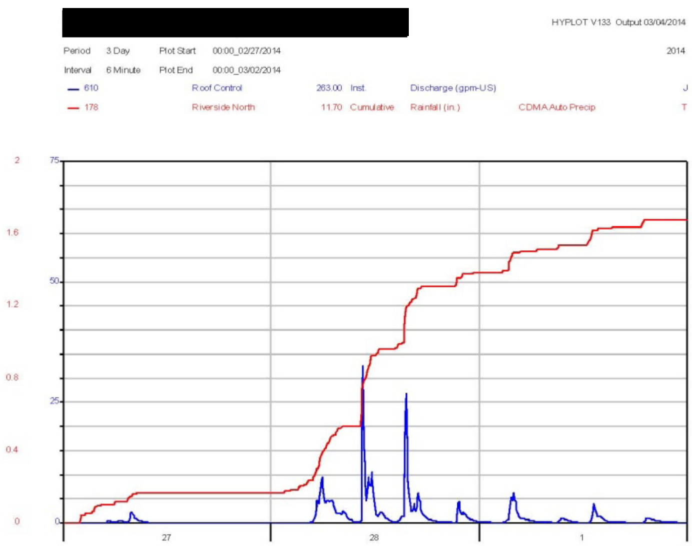


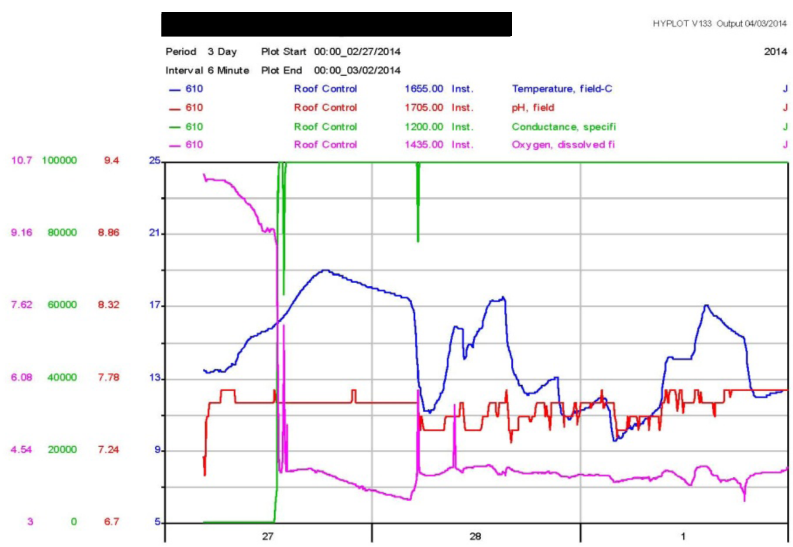


Note: Specific Conductance readings suspect-probe read only 6 or 4 through the entire storm. Probe may not have been fully submerged due to required set up of rain garden design. See different scale compared to 601-608.

13-14 02/28/14 Sampled Storm Event –Roof Runoff Control

Hydstra site ID	Description	Amount of Rain (inches)	Drainage Area (acres)	Theoretical Maximum runoff Volume (gallons)	Measured Runoff Volume (gallons)	Calculated water withheld (gallons)	Calculated Percentage loss (gain)	Approx. time rain began (Time)	Flow began-Isco (Time)	Lag Time (Min)	Flow ended (Date Time)
610	Roof Runoff Control										





Note: Specific Conductance readings suspect-probe read maximum of 10,000 during parts of the storm. See different scale compared to 601-608

Observations of Wet Weather Preliminary Data

Pavement Control (601) vs. Pavement BMP's –
Porous Concrete with Filter (602), Concrete without Filter (603), Asphalt with Filter (604), and Asphalt without Filter (605)
4 data points

- Decreases in Phosphorus, Ammonia, and Zinc
- Increases in Iron and Manganese
- Seems to be correlation between increase in Copper and Asphalt in 604 and 605
  - With the first three storms sampled between 2012-2013 there seemed to be correlation between increases in Lead and the Filter material in 602 and 604 however with 2014 data Lead now appears to be decreasing in 604; perhaps flushing out of construction materials?

Infiltration Basin Influent (608) vs. Effluent (606)
3 data points for general chemistry of Influent, 4 data points for Effluent and O&G Influent

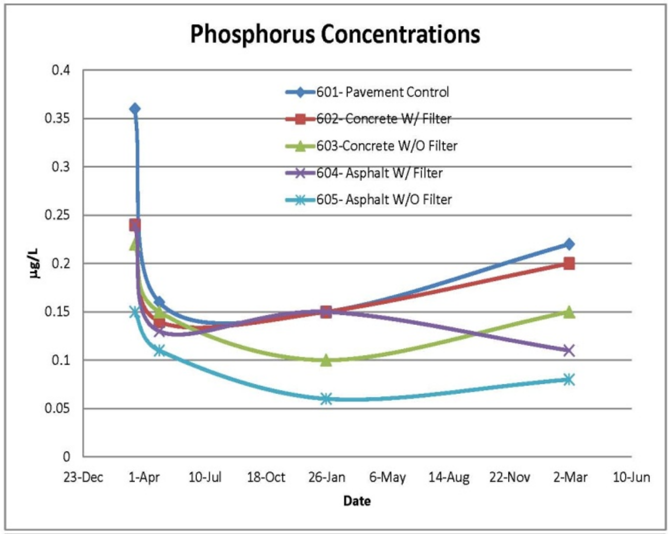
- Decrease in Oil & Grease

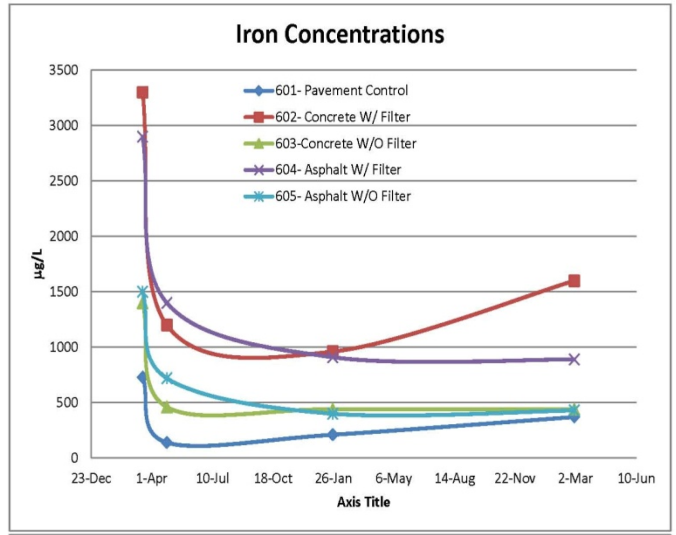
Roof Runoff Control (610) vs. Planter Box 1 / Rain Garden (609)
3 data points

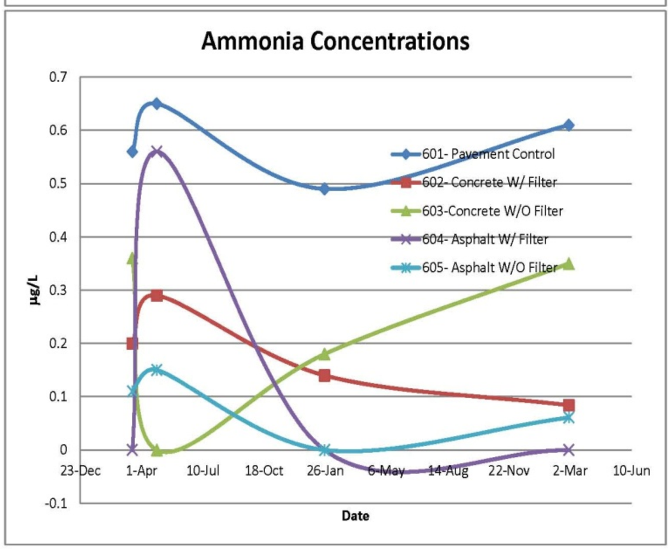
- Decrease in Ammonia, and Zinc
- Increase in Copper

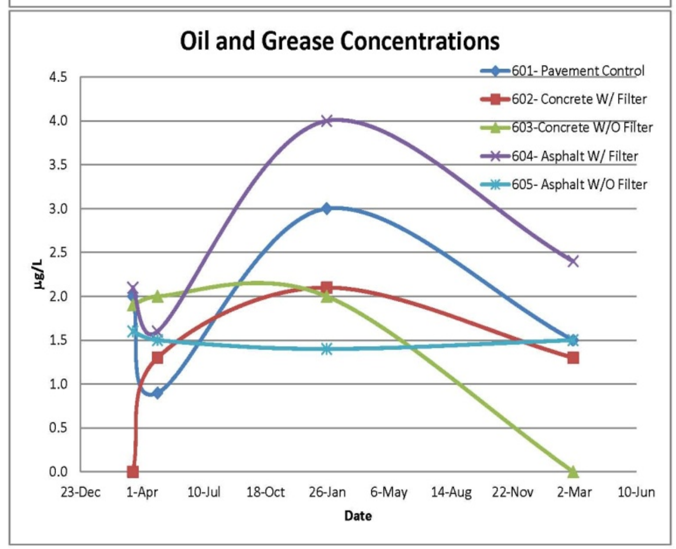
Preliminary Data

Pavement Control (601) vs. Pavement BMP's Porous Concrete with Filter (602), Concrete without Filter (603), Asphalt with Filter (604), and Asphalt without Filter (605)

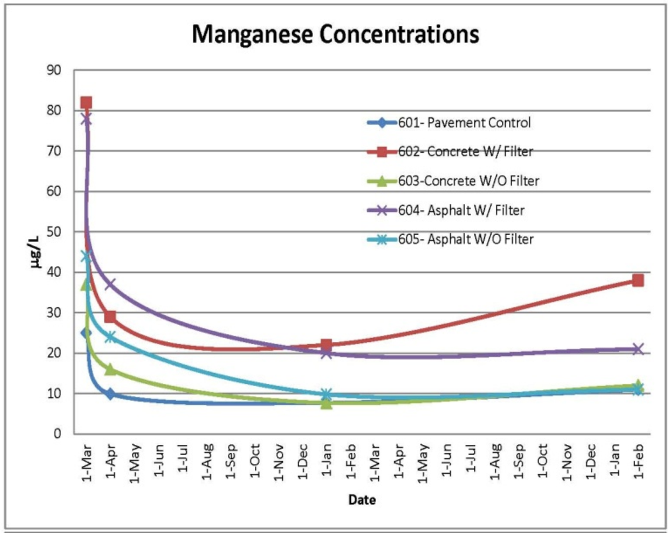


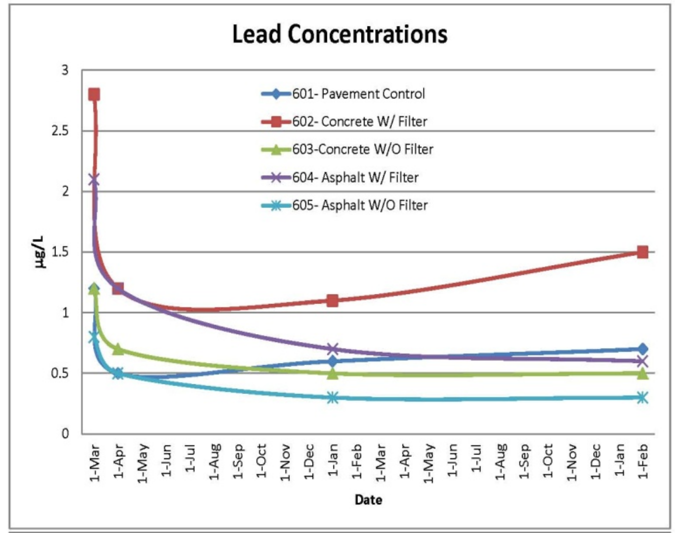


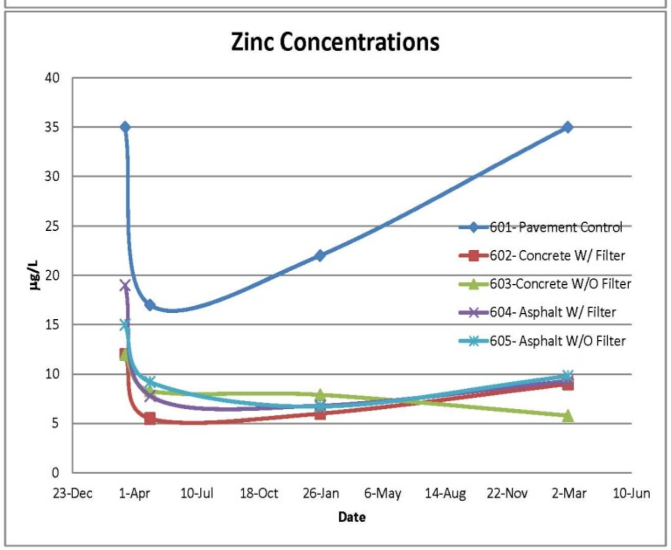


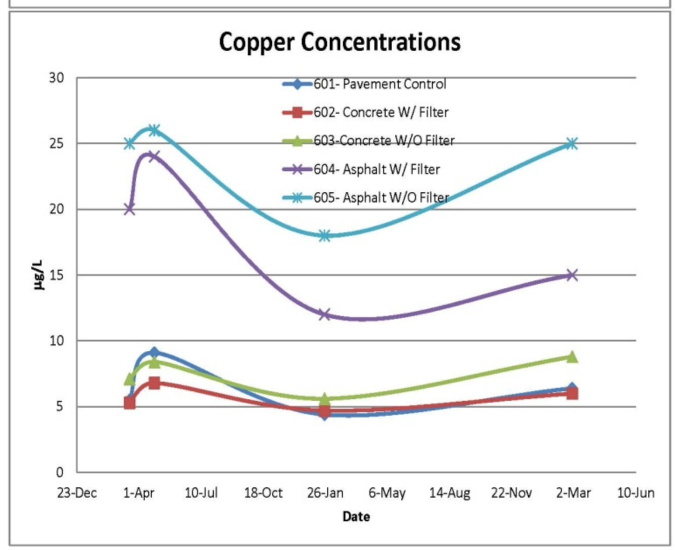


Preliminary Data
Pavement Control (601) vs. Pavement BMP's Porous Concrete with Filter (602), Concrete without Filter (603), Asphalt with Filter (604), and Asphalt without Filter (605) continued.

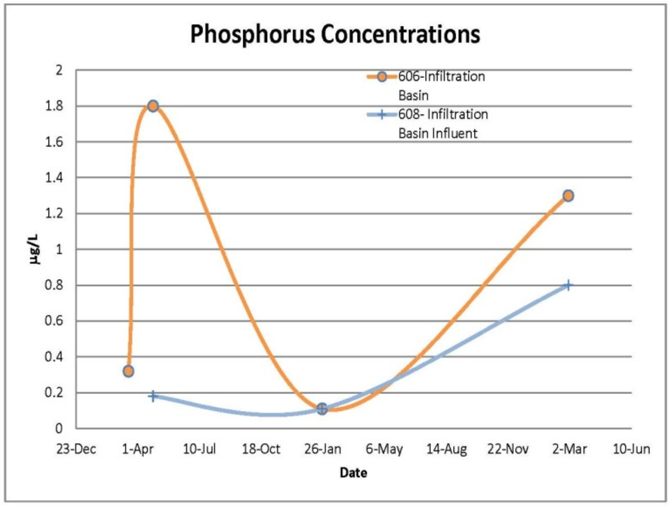


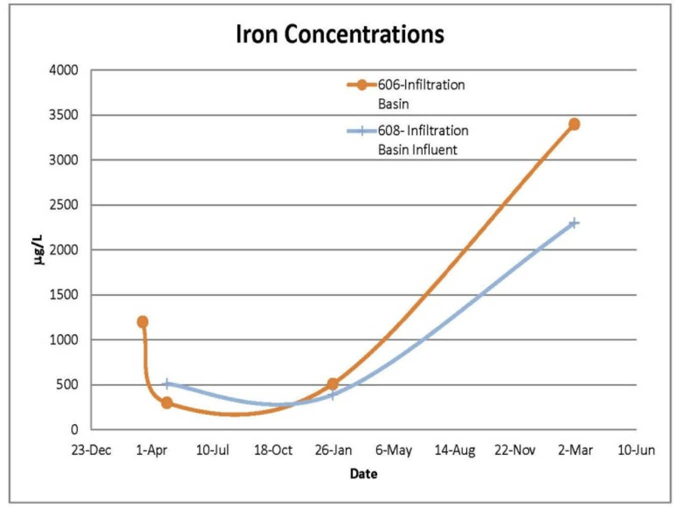


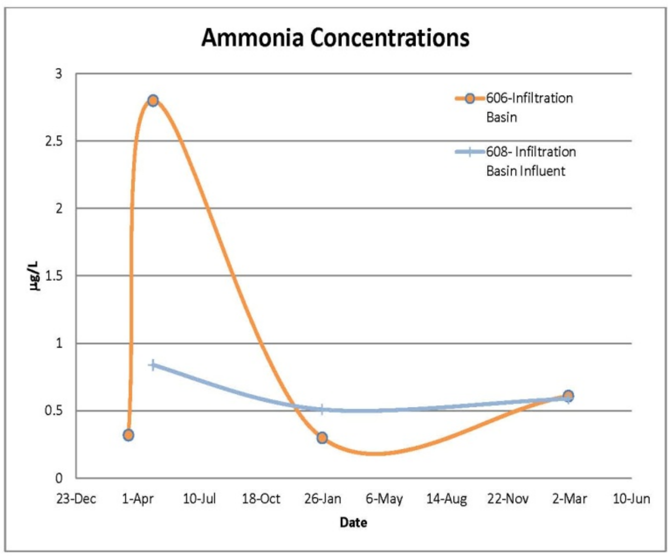


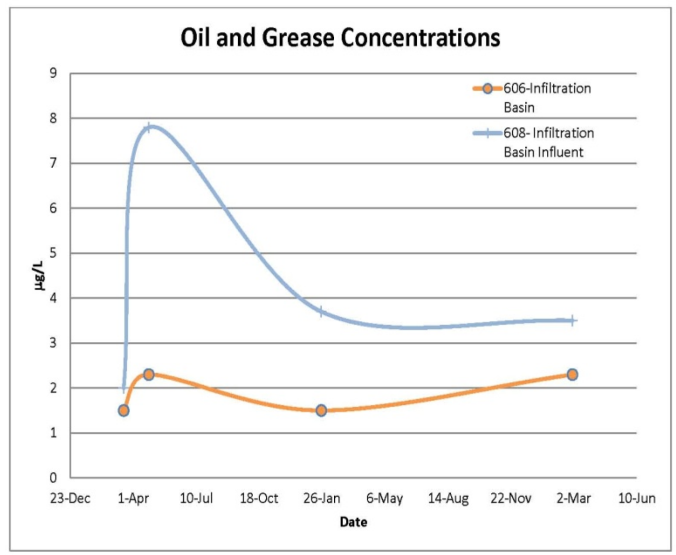


Preliminary Data
Infiltration Basin Influent (608) vs. Effluent (606)

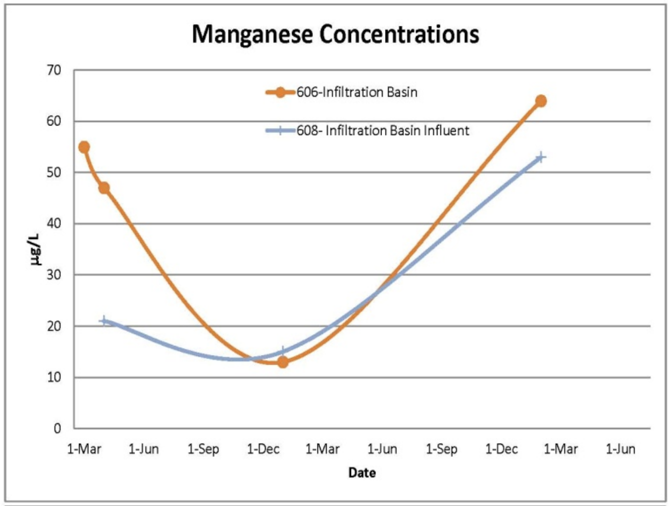


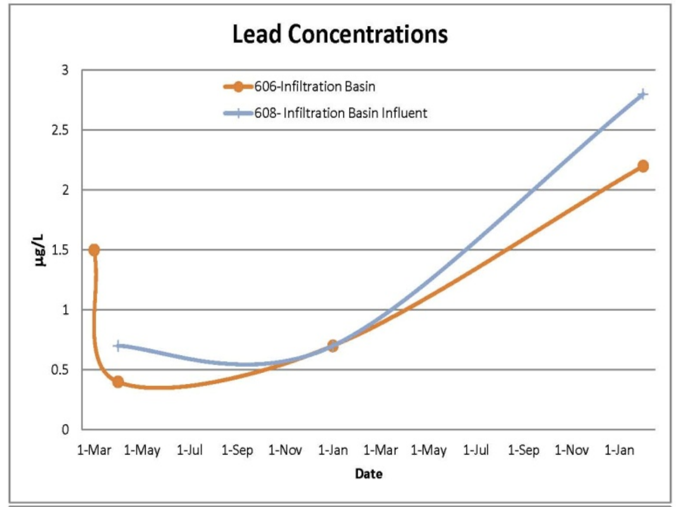


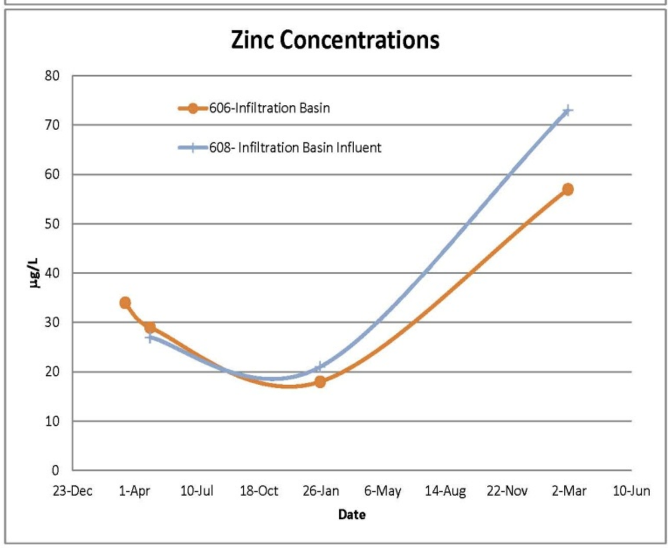


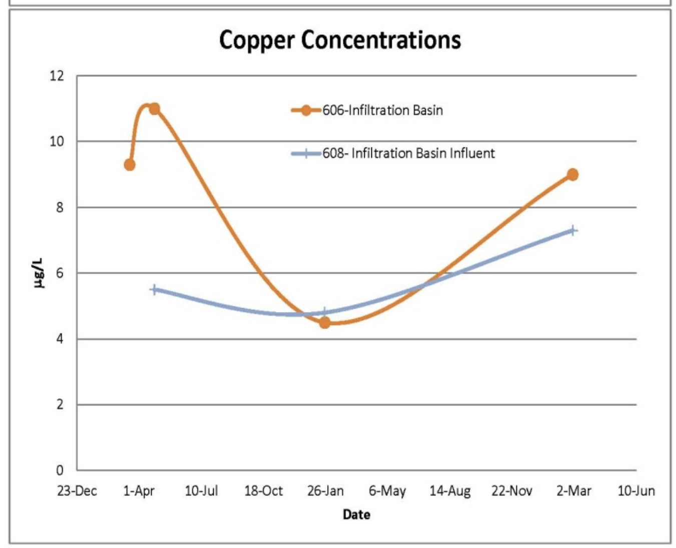


Preliminary Data
Infiltration Basin Influent (608) vs. Effluent (606) continued.

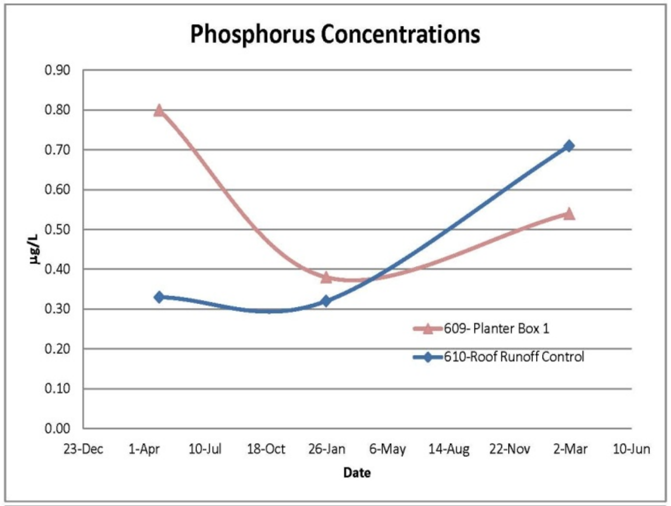


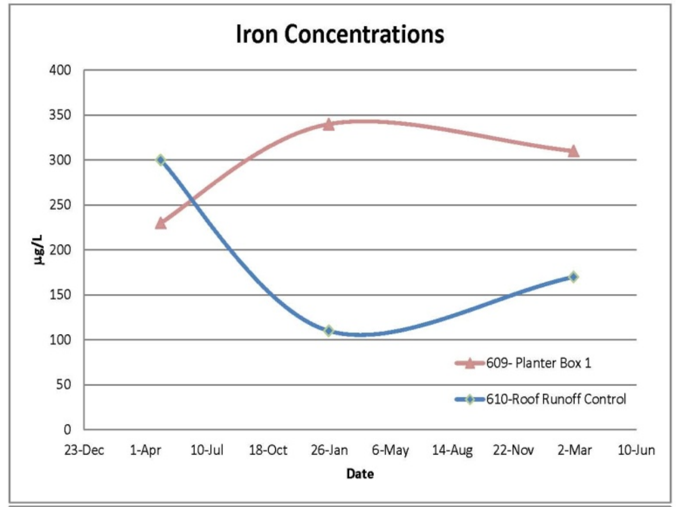


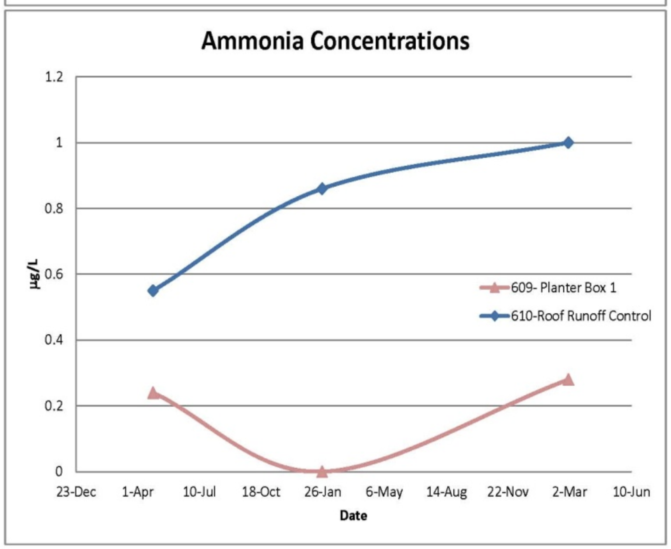


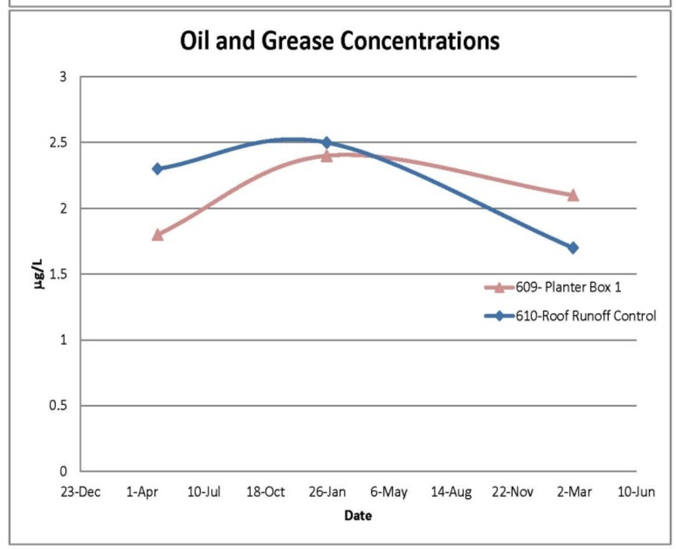


Preliminary Data
Roof Runoff Control (610) vs. Planter Box 1 / Rain Garden (609)

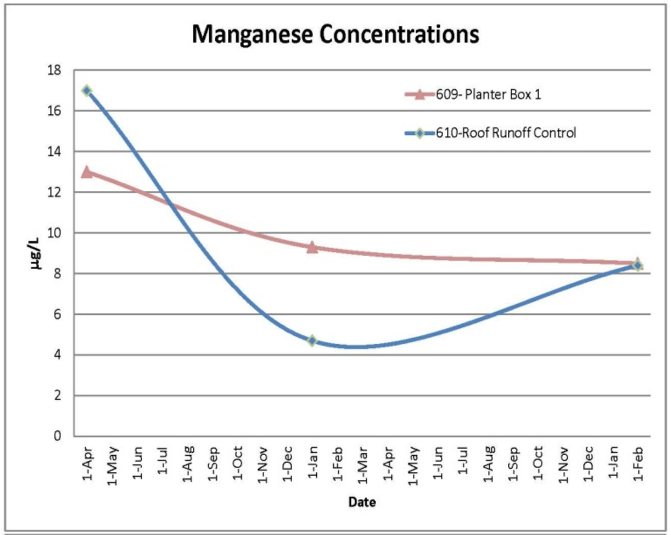


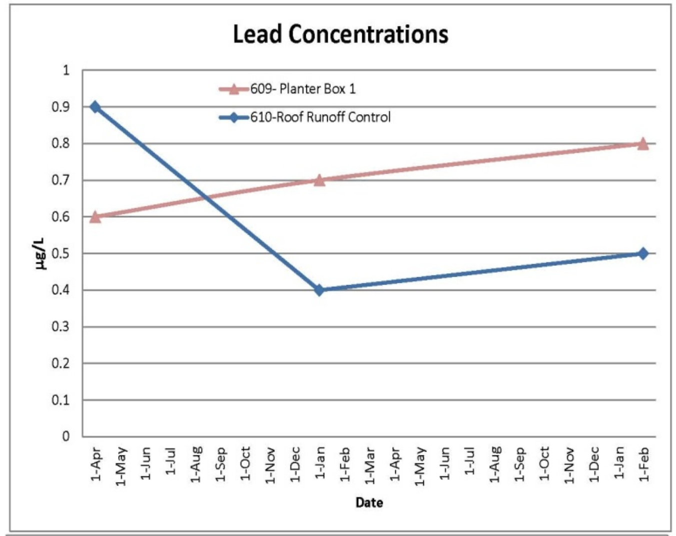


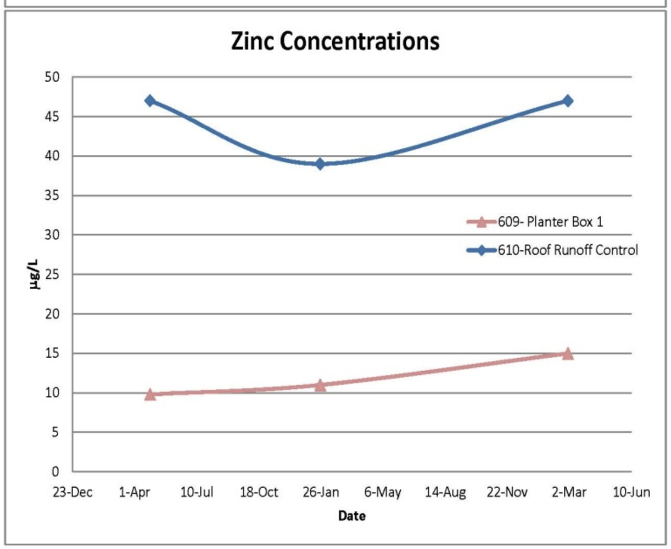


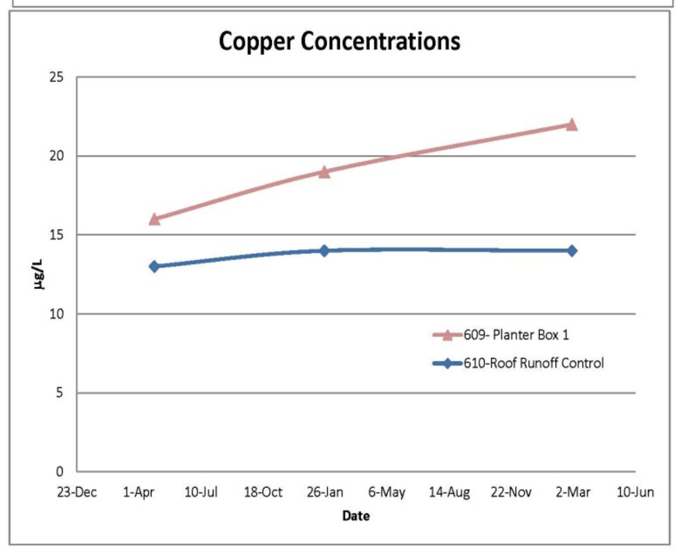


Preliminary Data
Roof Runoff Control (610) vs. Planter Box 1 / Rain Garden (609) continued.









2/28/2014
Storm Event

Analyte	RDL	MDL	Units	601- Pavement Control Results Flags	602- Concrete W/ Filter Results Flags	603-Concrete W/O Filter Results Flags	604- Asphalt W/ Filter Results Flags	605- Asphalt W/O Filter Results Flags	606-Infiltration Basin Results Flags	608- Infiltration Basin Influent Results Flags	609- Planter Box 1 Results Flags	610-Roof Runoff Control Results Flags
Grab Sample												
O&G	–	–	mg/L	1.5 J, NBLKprj, NRLrcf, Pblkl (RDL 2.6, MDL 1.0)	1.3 J, NBLKprj, NRLrcf, Pblkl (RDL 2.6, MDL 1.0)	ND <2.7 NBLKprj, NRLrcf, (RDL 2.7, MDL 1.0)	2.4 J, NBLKprj, NRLrcf, Pblkl (RDL 2.8, MDL 1.0)	1.5 NBLKprj, NRLrcf, (RDL 2.7, MDL 1.0)	2.3 J, NBLKprj, NRLrcf, Pblkl (RDL 2.6, MDL 1.0)	3.5 NRLrcf	2.1 J, NRLrcf, Pblkl (RDL 2.6, MDL 1.0)	1.7 J, NRLrcf (RDL 2.6, MDL 1.0)
E. Coli	2		MPN/100mL	>1600	9.0	>1600	2	23	30	11	2.0	8.0
Cations												
total hardness	3.0	0.35	mg/L	14 NRLrcf	38 NRLrcf	31 NRLrcf	70 NRLrcf	57 NRLrcf	41 NRLrcf	27 NRLrcf	73 NRLrcf	26 NRLrcf
Anions												
Nitrate as N	0.20	0.11	mg/L	ND <10 N_Htsa, Nconf, NRLrcf	1.3 NRLrcf	1.1 NRLrcf	2 NRLrcf	1.8 NRLrcf	0.47 NRLrcf	0.32 NRLrcf	2.5 NRLrcf	0.63 NRLrcf
Solids												
TDS	10	5.5	mg/L	760 NRLrcf	85	120	110	94	30	<10	140	31
TSS	5	3	mg/L	9 NRLrcf	22 NRLrcf	6 NRLrcf	10 NRLrcf	6 NRLrcf	52 NRLrcf	44 NRLrcf	6 NRLrcf	4 NRLrcf, J
Total Organic Carbon	0.70	0.16	mg/L	7.9 NRLrcf	8.2 NRLrcf	9.0 NRLrcf	13 NRLrcf	15 NRLrcf	5.5 NRLrcf	5.4 NRLrcf	25 NRLrcf	15 NRLrcf
Dissolved Organic Carbon	0.70	0.16	mg/L	6 N-TOCd, NRLrcf	7.6 N-TOCd	8.3 N-TOCd, NRLrcf	12 N-TOCd, NRLrcf	14 N-TOCd, NRLrcf	4.7 N-TOCd, NRLrcf	4.6 N-TOCd, NRLrcf	25 N-TOCd, NRLrcf	14 N-TOCd, NRLrcf
Total Petroleum Hydrocarbons	1	0.5	mg/L	ND <1.0	ND <1.0	ND <1.0	ND <1.0	ND <1.0	0.59 J	0.76 J	ND <1.0	ND <1.0
Nutrients												
Nirtrite as N	0.1	0.017	mg/L	ND <0.1	0.04 J	0.030 J	ND <0.10	0.020 J	ND <0.10	ND <0.10	0.090 J	0.10
Ammonia-Nitrogen	0.10	0.059	mg/L	0.61 NRLrcf	0.084 J, NRLrcf	0.35 NRLrcf	ND <0.10 NRLrcf	0.061 J, NRLrcf	0.61 NRLrcf	0.59 NRLrcf	0.28 NRLrcf	1.0 NRLrcf
Kjeldahl Nitrogen	0.20	0.13	mg/L	1.1	0.47	0.73	0.55	0.77	1.1	1.1	1.7	1.9
Total Nitrogen	0.10	5.4	mg/L	ND <10 J	1.8	1.9	2.6	2.6	1.60	1.4	4.3	2.6
Ortho Phosphate Phosphorus	0.050	0.0028	mg/L	0.17 NRLrcf	0.14 NRLrcf	0.11 NRLrcf	0.09 NRLrcf	0.046 J, NRLrcf, Pblkl	0.87 NRLrcf	0.42 NRLrcf	0.48 NRLrcf	0.54 NRLrcf
Total Phosphorus	0.05	0.01	mg/L	0.22	0.20	0.15	0.11	0.08	1.3 NRLrcf	0.80 NRLrcf	0.54	0.71
Diesel Range Organics												
Motor Oil	5.0	5.0	mg/L	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)
Diesel Range Hydrocarbons	5.0	0.46	mg/L	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)
Metals and Metalloids-Total												
Arsenic	1.0	0.08	µg/L	ND <0.1	5.1	4	2.9	1.0	0.9 J	0.9 J	2.4	0.7 J
Cadmium	0.25	0.01	µg/L	ND <0.25	ND<0.25	ND<0.25	ND<0.25	ND<0.25	ND<0.25	ND<0.25	ND<0.25	ND<0.25
Total Chromium	0.5	0.4	µg/L	0.7	1.9	1.1	0.8	0.5	3.1	2.4	0.9	0.5
Copper	0.5	0.04	µg/L	6.4	6.0	8.8	15	25	9.0	7.3	22	14
Iron	50	2.3	µg/L	370	1600	440	890	430	3400	2300	310	170
Lead	0.5	0.03 µg/L		0.7	1.5	0.5	0.6	0.3 J	2.2	2.8	0.8	0.5
Manganese	10	0.17	µg/L	11	38	12	21	11	64	53	8.5 J	8.4 J
Nickel	1.0	0.06	µg/L	1.0	0.9 J	1.0	1.6	3.3	2.7	2.3	1.7	1.0
Zinc	1.0	0.03	µg/L	35	9.0	5.8	9.3	9.8	57	73	15	47
Metals and Metalloids-Dissolved												
Arsenic	1.0	0.08	µg/L	ND <1.0 N_pFilt	4.6 N_pFilt	4.1 N_pFilt	2.8 N_pFilt	0.9 N_pFilt, J	0.7 N_pFilt, J	ND <1.0 N_pFilt, J	2.4 N_pFilt	0.7 N_pFilt, J
Cadmium	0.25	0.01	µg/L	ND<.25 N_pFilt	ND <.25 N_pFilt	ND<.25 N_pFilt	ND<.25 N_pFilt	ND<.25 N_pFilt	ND <.25 N_pFilt	ND <.25 N_pFilt, J	ND <.25 N_pFilt	ND <.25 N_pFilt
Total Chromium	0.5	0.4	µg/L	ND<0.5 N_pFilt	0.9 N_pFilt	0.9 N_pFilt	0.5 N_pFilt	ND <0.5 N_pFilt	0.4 N_pFilt, J	ND <0.5 N_pFilt	0.7 N_pFilt	0.4 N_pFilt, J
Copper	0.5	0.04	µg/L	4.6 N_pFilt	4.5 N_pFilt	8.2 N_pFilt	14 N_pFilt	24 N_pFilt	4.8 N_pFilt	2.3 N_pFilt	19 N_pFilt	12 N_pFilt
Iron	50	2.3	µg/L	20 N_pFilt, J	22 N_pFilt, J	14 N_pFilt, J	12 N_pFilt, J	15 N_pFilt, J	20 N_pFilt, J	19 N_pFilt, J	22 N_pFilt, J	6.7 N_pFilt, J
Lead	0.5	0.03	µg/L	0.2 N_pFilt, J	ND<0.5 N_pFilt	0.2 N_pFilt, J	ND<0.5 N_pFilt	ND <0.5 N_pFilt	0.3 N_pFilt, J	ND <0.5 N_pFilt	ND <0.5 N_pFilt	ND <0.5 N_pFilt
Manganese	10	0.17	µg/L	ND <10 N_pFilt	ND<10 N_pFilt	ND<10 N_pFilt	ND<10 N_pFilt	ND<10 N_pFilt	7.2 N_pFilt, J	ND<10 N_pFilt, J	ND<10 N_pFilt	ND<10 N_pFilt
Nickel	1.0	0.06	µg/L	0.7 N_pFilt, J	0.5 N_pFilt, J	0.8 N_pFilt, J	1.5 N_pFilt	3.1 N_pFilt	1.0 N_pFilt	0.6 N_pFilt, J	1.4 N_pFilt	0.9 N_pFilt, J
Zinc	1.0	0.03	µg/L	37 N_pFilt	3.8 N_pFilt	4.4 N_pFilt	7.9 N_pFilt	11 N_pFilt	13 N_pFilt	40 N_pFilt	9.5 N_pFilt	38 N_pFilt

Flags

Pblkl = The analyte was detected in the Method Blank at a concentration between the MDL and MRL

J = Estimated Value

ND = Analyte NOT DETECTED at or above the Method Detection limit (if MDL is reported), otherwise at or above the Reportable Detection limit (RDL)

N_pFilt = Sample filtered and preserved upon receipt to the laboratory

N-TOCd = Sample filtered and preserved at laboratory after 15 minute regulatory holding time

Nfilt = This sample was filtered prior to analysis

N_HTc = Original result is reported, since it is wintin EPA recommended holding time an dconfirmed by reanalysis

Preliminary Data

1/25/2013
Storm Event

Analyte	RDL	MDL	Units	601- Pavement Control Results / Flags	602- Concrete W/ Filter Results / Flags	603-Concrete W/O Filter Results / Flags	604- Asphalt W/ Filter Results / Flags	605- Asphalt W/O Filter Results / Flags	606-Infiltration Basin Results / Flags	608- Infiltration Basin Influent Results / Flags	609- Planter Box 1 Results / Flags	610-Roof Runoff Control Results / Flags
Grab Sample												
O&G	--	--	mg/L	3.0 (RDL 2.5, MDL 0.9)	2.1 J (RDL 2.5, MDL 0.9)	2.0 J (RDL 2.5, MDL 0.9)	4.0 (RDL 2.6, MDL 1.0)	1.4 J (RDL 2.6, MDL 1.0)	1.5 J (RDL 2.5, MDL 0.9)	3.7 (RDL 2.5, MDL 0.9)	2.4 J (RDL 2.8, MDL 1.0)	2.5 (RDL 2.5, MDL 0.9)
E. Coli	2000		MPN/100mL	ND (>2000)	ND (>2000)	ND (>2000)	ND (>2000)	ND (>2000)	ND (>2000)	ND (>2000)	ND (>2000)	ND (>2000)
Cations												
total hardness	3.0	0.35	mg/L	9.7	30	26	50	37	25	23	130	33
Anions												
Nitrate as N	0.20	0.11	mg/L	0.38	0.70	0.63	1.4	1.0	0.27	0.27	1.5	0.74
Solids												
TDS	10	5.5	mg/L	31	94	110	110	90	53	42	280	78
TSS	5	3	mg/L	13	16	9	10	4 N_HTc, J	10 N_HTc	4 N_HTc, J	5	4
Total Organic Carbon	0.70	0.16	mg/L	5.5	7.2	5.9	9.2	10	5.5	7.1	22 PblkJ	17
Dissolved Organic Carbon	0.70	0.16	mg/L	3.2 N-TOCd	4.3 N-TOCd	4.7 N-TOCd	7.3 N-TOCd	7.9 N-TOCd	4.7 N-TOCd	5.7 N-TOCd	20 N-TOCd	14
Total Petroleum Hydrocarbons	1	0.5	mg/L	ND <1.0	ND <1.0	ND <1.0	ND <1.0	ND <1.0	ND <1.0	0.84 J	ND <1.0	ND <1.0
Nutrients												
Ammonia-Nitrogen	0.10	0.059	mg/L	0.49	0.14	0.18	ND <0.10	ND <0.10	0.30	0.51	ND <0.10	0.86
Kjeldahl Nitrogen	0.20	0.13	mg/L	0.86	0.54	0.56	0.54	0.50	0.54	0.94	1.7	1.8
Ortho Phosphate Phosphorus	0.050	0.0028	mg/L	0.074	0.094	0.070	0.10	0.032 J	0.065	0.056	0.26	0.32
Total Phosphorus	0.05	0.01	mg/L	0.15	0.15	0.10	0.15	0.06	0.11	0.11	0.38	0.32
Diesel Range Organics												
Motor Oil	2.3	2.3	mg/L	ND (<2.3)	ND (<2.3)	ND (<2.3)	ND (<2.3)	ND (<2.3)	ND (<2.3)	ND (<2.3)	ND (<2.3)	ND (<2.3)
Diesel Range Hydrocarbons	5.7	0.52	mg/L	ND (<5.7)	ND (<5.7)	ND (<5.7)	ND (<5.7)	ND (<5.7)	ND (<5.7)	ND (<5.7)	ND (<5.7)	ND (<5.7)
Metals and Metalloids-Total												
Arsenic	1.0	0.08	µg/L	0.4 J	5.4	4.0	2.6	0.9 J	0.6 J	0.5 J	2.8	0.9
Cadmium	0.25	0.01	µg/L	0.09 J	0.02 J	ND <.25	0.02 J	0.03 J	0.02 J	0.02 J	0.04 J	0.03
Total Chromium	0.5	0.4	µg/L	0.7	2.4	1.6	0.8	0.5	0.9	0.8	1.3	0.8
Copper	0.5	0.04	µg/L	4.4	4.7	5.6	12	18	4.5	4.8	19 PblkJ	14
Iron	50	2.3	µg/L	210	960	440	910	400	510	390	340 PblkJ	110
Lead	0.5	0.03	µg/L	0.6	1.1	0.5	0.7	0.3 J	0.7	0.7	0.7	0.4
Manganese	10	0.17	µg/L	7.7 J	22	11	20	9.8 J	13	15	9.3 J	4.7
Nickel	1.0	0.06	µg/L	0.8 J	1.1 J	0.7	1.3	2.3	1.0	1.0	1.9	1.1
Zinc	1.0	0.03	µg/L	22	6	7.9 J	6.8	6.7	18	21	11	39
Metals and Metalloids-Dissolved												
Arsenic	1.0	0.08	µg/L	0.3 N_pFilt, J	4.9 N_pFilt	3.9 N_pFilt	2.3 N_pFilt	0.8 N_pFilt, J	0.5 N_pFilt, J	0.6 N_pFilt, J	2.6 N_pFilt	0.8 N_pFilt, J
Cadmium	0.25	0.01	µg/L	ND<.25 N_pFilt	ND <.25 N_pFilt	ND <.25 N_pFilt	0.02 N_pFilt, J	0.06 N_pFilt, J	ND <.25 N_pFilt	0.01 N_pFilt, J	0.03 N_pFilt, J	0.03 N_pFilt, J
Total Chromium	0.5	0.4	µg/L	0.4 N_pFilt, J	1.3 N_pFilt	1.2 N_pFilt	0.4 N_pFilt, J	ND <0.5 N_pFilt	0.4 N_pFilt, J	0.5 N_pFilt	0.9 N_pFilt	0.7 N_pFilt
Copper	0.5	0.04	µg/L	2.6 Nfilt	2.7 Nfilt	4.3 Nfilt	9.2 Nfilt	16 N_pFilt	3.5 N_pFilt	3.9 N_pFilt	18 N_pFilt	13 N_pFilt
Iron	50	2.3	µg/L	15 N_pFilt, J	8.4 N_pFilt, J	15 N_pFilt, J	8.2 N_pFilt, J	6.9 N_pFilt, J	12 N_pFilt, J	8.9 N_pFilt, J	16 N_pFilt, J	18 N_pFilt, J
Lead	0.5	0.03	µg/L	0.2 N_pFilt, J	0.04 N_pFilt, J	0.09 N_pFilt, J	0.07 N_pFilt, J	ND <0.5 Nfilt	0.03 Nfilt, J	ND <0.5 Nfilt	0.5 N_pFilt	0.04 Nfilt, J
Manganese	10	0.17	µg/L	3.3 N_pFilt, J	0.92 N_pFilt, J	2.3 N_pFilt, J	1.4 N_pFilt, J	1.8 N_pFilt, J	3.2 N_pFilt, J	2.4 N_pFilt, J	1.7 N_pFilt, J	0.62 N_pFilt, J
Nickel	1.0	0.06	µg/L	1.1 N_pFilt	0.7 N_pFilt, J	1.4 N_pFilt	2.0 N_pFilt	2.0 N_pFilt	0.7 N_pFilt, J	0.9 N_pFilt, J	1.6 N_pFilt	1.0 N_pFilt
Zinc	1.0	0.03	µg/L	16 Nfilt	ND <1.0 Nfilt	2.1 Nfilt	2.6 Nfilt	4.2 Nfilt	22 Nfilt	10 Nfilt	5.1 Nfilt	31 Nfilt

Flags

PblkJ = The analyte was detected in the Method Blank at a concentration between the MDL and MRL
J = Estimated Value
ND = Analyte NOT DETECTED at or above the Method Detection Limit (if MDL is reported), otherwise at or above the Reportable Detection Limit (RDL)
N_pFilt = Sample filtered and preserved upon receipt to the laboratory
N-TOCd = Sample filtered and preserved at laboratory after 15 minute regulatory holding time
Nfilt = This sample was filtered prior to analysis
N_HTc = Original result is reported, since it is wintin EPA recommended holding time an dconfirmed by reanalysis

Preliminary Data

8/10/2012
Dry Weather Test

Analyte	RDL	MDL	Units	601- Pavement Control Results	601 Flags	602- Concrete W/ Filter Results	602 Flags	603-Concrete W/O Filter Results	603 Flags	604- Asphalt W/ Filter Results	604 Flags	605- Asphalt W/O Filter Results	605 Flags	600- Water Blank Results	600 Flags
Grab Sample															
O&G	--	--	mg/L	2.5	PblkJ (RDL 2.5, MDL 0.9)	1.4	J (RDL 2.5, MDL 0.9)	1.3	PblkJ, J (RDL 2.5, MDL 0.9)	1.2	J (RDL 2.5, MDL 0.9)	1.5	J (RDL 2.5, MDL 0.9)	2.3	PblkJ, J (RDL 2.5, MDL 0.9)
E. Coli	200		MPN/100mL	700		800		800		ND (>200)		ND (>200)		ND (>2.0)	
Cations															
total hardness	3.0	0.35	mg/L	220		110		110		260		310		210	
Anions															
Nitrate as N	0.20	0.11	mg/L	4.8		7.7		6.7		7.0		7.5		4.7	
Solids															
TDS	10	5.5	mg/L	430		350		460		490		610		380	
TSS	5	3	mg/L	56		130		160		60		50		ND <5	
Total Organic Carbon	0.70	0.16	mg/L	24		12		12		18		35		ND <0.70	
Dissolved Organic Carbon	0.70	0.16	mg/L	21	N-TOCd	11	N-TOCd	11	N-TOCd	16	N-TOCd	30	N-TOCd	0.29	N-TOCd, J
Nutrients															
Ammonia-Nitrogen	0.10	0.059	mg/L	0.71		ND (<0.10)		0.11		0.16		0.32		ND < 0.10	
Kjeldahl Nitrogen	0.20	0.13	mg/L	2.4		1.5		1.4		1.6		2.4		ND < 0.40	N_RLm
Ortho Phosphate Phosphorus	0.050	0.0028	mg/L	0.095		0.16		0.082		0.065		<0.050		0.025	J
Total Phosphorus	0.05	0.01	mg/L	0.24		0.42		0.57		0.20		0.17		0.07	
Diesel Range Organics															
Motor Oil	5.7	5.7	mg/L	ND <5.0		ND <5.0		ND <5.0		ND <5.0		ND <5.0		ND <5.0	
Diesel Range Hydrocarbons	5.7	0.52	mg/L	0.79	J, NHCno, PblkJ	0.77	J, NHCno, PblkJ	0.77	J, NHCno, PblkJ	0.77	J, NHCno, PblkJ	0.77	J, NHCno, PblkJ	0.93	J, NHCno, PblkJ
Metals and Metalloids-Total															
Arsenic	1.0	0.08	µg/L	2.3		12		12		4.8		2.8		1.9	
Cadmium	0.25	0.01	µg/L	0.05	J	0.16	J	0.17	J	0.14	J	0.29		ND <0.25	
Total Chromium	0.5	0.4	µg/L	4.2		7.3		9.2		6.0		4.3		1.9	
Copper	0.5	0.04	µg/L	17		11		20		29	NBLK10x	50	NBLK10x	1.9	
Iron	50	2.3	µg/L	1200	Pblk	7500	Pblk	6600	PblkJ	3500	PblkJ	2800	PblkJ	4.5	J
Lead	0.5	0.03	µg/L	3.7		6.2		5.7		1.4		1.3		0.1	J
Manganese	10	0.17	µg/L	61	J	180		160		88		130		0.18	J
Nickel	1.0	0.06	µg/L	3.4		2.4		3.2		6.0		12		0.4	J
Zinc	1.0	0.03	µg/L	60		22		41		16		25		1.2	

Flags

PblkJ = The analyte was detected in the Method Blank at a concentration between the MDL and MRL

J = Estimated Value

ND = Analyte NOT DETECTED at or above the Method Detection Limit (if MDL is reported), otherwise at or above the Reportable Detection Limit (RDL)

N_RLm = Due to sample matrix, the reporting limit has been raised

N-TOCd = Sample filtered and preserved at laboratory after 15 minute regulatory holding time

NBLK10 = Analyte was detected at 0.268 ug/L in the Method Blank. Since sample result is equal to or greater than ten times the blank result, this bias is considered to be negligible

NHCno = The sample chromatographic pattern does NOT resemble the fuel standard used for quantitation

4/26/2012
Storm Event

Analyte	RDL	MDL	Units	601- Pavement Control Results Flags	602- Concrete W/ Filter Results Flags	603-Concrete W/O Filter Results Flags	604- Asphalt W/ Filter Results Flags	605- Asphalt W/O Filter Results Flags	606-Infiltration Basin Results Flags	608- Infiltration Basin Influent Results Flags	609- Planter Box 1 Results Flags	610-Roof Runoff Control Results Flags
Grab Sample												
O&G	--	--	mg/L	0.9 PblkJ, J (RDL 2.5, MDL 0.9)	1.3 PblkJ, J (RDL 2.5, MDL 0.9)	2.0 PblkJ, J (RDL 2.5, MDL 0.9)	1.6 PblkJ, J (RDL 2.5, MDL 0.9)	1.5 PblkJ, J (RDL 2.5, MDL 0.9)	2.3 PblkJ, J (RDL 2.8, MDL 1.0)	7.8 PblkJ (RDL 3.0, MDL 1.1)	1.8 PblkJ, J (RDL 2.5, MDL 0.9)	2.3 PblkJ, J (RDL 2.9, MDL 1.1)
E. Coli	200		MPN/100mL	ND (>200)	ND (>200)	ND (>200)	ND (>200)	ND (>200)	ND (>200)	400	200	ND (>200)
Cations												
total hardness	3.0	0.35	mg/L	9.9	51	40	46	37	77	19	200	22
Calcium	1.0	0.50	mg/L	3.2	15	14	12	10	23	6.0	57	7.6
Magnesium	1.0	0.50	mg/L	ND <1.0	2.9	1.3	4	2.9	4.8	0.87	13	0.85
Anions												
Nitrate as N	0.20	0.11	mg/L	0.47	1.5	0.93	1.9	1.7	0.81	0.38	1.2	0.61
Solids												
TDS	10	5.5	mg/L	36	150	110	130	120	170	49	340	38
TSS	5	3	mg/L	ND <10	20	12	18	12	6	12	6	8
Total Organic Carbon	0.70	0.16	mg/L	13	22	19	22	22	33	15	18	14
Dissolved Organic Carbon	0.70	0.16	mg/L	11 N-TOCd	19 N-TOCd	15 N-TOCd	19 N-TOCd	18 N-TOCd	26 N-TOCd	11 N-TOCd	16	12
Total Petroleum Hydrocarbons	1	0.5		ND <1.0	ND <1.0	ND <1.0	ND <1.0	ND <1.0	ND <1.0	ND <1.0	ND <1.0	ND <1.0
Nutrients												
Ammonia-Nitrogen	0.10	0.059	mg/L	0.65	0.29	ND (<0.10)	0.56	0.15	2.8	0.84	0.24	0.55
Kjeldahl Nitrogen	0.20	0.13	mg/L	1.2	1.1	1.1	1.4	1.2	4.2	1.7	1.7	2.4
Ortho Phosphate Phosphorus	0.050	0.0028	mg/L	0.095	0.063	0.095	0.059	0.045 J	0.96	0.057	0.68	0.24
Total Phosphorus	0.05	0.01	mg/L	0.16	0.14	0.15	0.13	0.11	1.8	0.18	0.80	0.33
Diesel Range Organics												
Motor Oil	5.7	5.7	mg/L	ND (<6.9)	ND (<6.9) (RDL = 6.9)	ND (<5.7)	ND (<5.7)	ND (<5.7)	ND (<5.7)	ND (<5.7)	ND (<5.7)	ND (<5.7)
Diesel Range Hydrocarbons	5.7	0.52	mg/L	0.96 J, NHCno	ND (<5.7)	ND (<5.7)	ND (<5.7)	ND (<5.7)	ND (<5.7)	1.1 J, NHCno	ND (<5.7)	ND (<5.7)
Metals and Metalloids-Total												
Arsenic	1.0	0.08	µg/L	0.4 J	7.9	4.8	3.5	1.9	1.5	0.5 J	7.0	0.8
Cadmium	0.25	0.01	µg/L	<.25	0.04 J	0.03 J	0.09 J	0.09 J	0.05 J	0.03 J	0.06	0.04
Total Chromium	0.5	0.4	µg/L	0.7	3.2	2.4	1.4	1.1	1.7	1.1	2.0	1.1
Copper	0.5	0.04	µg/L	5.5	5.3	7.1	20	25	9.3	5.5	16	13
Iron	50	2.3	µg/L	140	1200	460	1400	720	300	510	230	300
Lead	0.5	0.03 µg/L		0.5	1.2	0.7	1.2	0.5	0.4 J	0.7	0.6	0.9
Manganese	10	0.17	µg/L	9.9 J	29	16	37	24	47	21	13	17
Nickel	1.0	0.06	µg/L	2.0	1.0	1.1	2.2	3.4	3.2	1.8	3.5	1.3
Zinc	1.0	0.03	µg/L	17	5.5	8.3	7.8	9.2	29	27	9.8	47
Metals and Metalloids-Dissolved												
Arsenic	1.0	0.08	µg/L	0.3 N_pFilt, J	6.6 N_pFilt	3.5 N_pFilt	2.8 N_pFilt	1.5 N_pFilt	1.3 N_pFilt	0.4 N_pFilt, J	6.3 N_pFilt	0.7 N_pFilt, J
Cadmium	0.25	0.01	µg/L	0.03 N_pFilt, J	0.04 N_pFilt, J	0.04 N_pFilt, J	0.06 N_pFilt, J	0.09 N_pFilt, J	0.06 N_pFilt, J	0.02 N_pFilt, J	0.04 N_pFilt, J	0.04 N_pFilt, J
Total Chromium	0.5	0.4	µg/L	0.6 N_pFilt	4.2 N_pFilt	2.0 N_pFilt	0.7 N_pFilt	0.6 N_pFilt	1.2 N_pFilt	0.5 N_pFilt	2.2 N_pFilt	0.7 N_pFilt
Copper	0.5	0.04	µg/L	5.1 N_pFilt	5.2 N_pFilt	5.8 N_pFilt	17 N_pFilt	23 N_pFilt	8.7 N_pFilt	4.2 N_pFilt	14 N_pFilt	12 N_pFilt
Iron	50	2.3	µg/L	18 N_pFilt, J	7.6 N_pFilt, J	20 N_pFilt, J	13 N_pFilt, J	22 N_pFilt, J	41 N_pFilt, J	21 N_pFilt, J	17 N_pFilt, J	15 N_pFilt, J
Lead	0.5	0.03	µg/L	0.1 N_pFilt, J	0.09 N_pFilt, J	0.08 N_pFilt, J	0.04 N_pFilt, J	0.09 N_pFilt, J	0.1 N_pFilt, J	0.07 N_pFilt	0.07 N_pFilt, J	0.07 N_pFilt, J
Manganese	10	0.17	µg/L	6.8 N_pFilt, J	1.6 N_pFilt, J	3.1 N_pFilt, J	4.2 N_pFilt, J	7 N_pFilt, J	34 N_pFilt	11 N_pFilt	2.1 N_pFilt, J	1.7 N_pFilt, J
Nickel	1.0	0.06	µg/L	1.1 N_pFilt	1.0 N_pFilt	0.8 N_pFilt, J	1.7 N_pFilt	2.9 N_pFilt	3.0 N_pFilt	1.3 N_pFilt	3.6 N_pFilt	1.1 N_pFilt
Zinc	1.0	0.03	µg/L	10 N_pFilt, NBLK10x	1.3 N_pFilt	3.0 N_pFilt	3.8 N_pFilt	7.6 N_pFilt	22 N_pFilt, NBLK10x	26 N_pFilt, NBLK10x	4.9 N_pFilt	30 N_pFilt, NBLK10x

Flags
PblkJ = The analyte was detected in the Method Blank at a concentration between the MDL and MRL
J = Estimated Value
ND = Analyte NOT DETECTED at or above the Method Detection Limit (if MDL is reported), otherwise at or above the Reportable Detection Limit (RDL)
N_pFilt = Sample filtered and preserved upon receipt to the laboratory
N-TOCd = Sample filtered and preserved at laboratory after 15 minute regulatory holding time
NBLK10 = Ama;ute was detected at 0.809ug/L in the Method Blank. Since sample result is equal to or greater than ten times the blank result, this bias is considered to be negligible
NHCno = The sample chromatographic pattern does NOT resemble the fuel standard used for quantitation

Preliminary Data

3/17/2012
Storm Event

				601- Pavement Control		602- Concrete W/ Filter		603-Concrete W/O Filter		604- Asphalt W/ Filter		605- Asphalt W/O Filter		606-Infiltration Basin		608- Infiltration Basin Influent		Blanks		
Analyte	RDL	MDL	Units	Results	Flags	Results	Flags	Results	Flags	Results	Flags	Results	Flags	Results	Flags	Results	Flags	Hose Water	ISCO bottles	System
Grab Sample																				
O&G	–	–	mg/L	2.0	Pblkl, J (RDL 2.7, MDL 1.0)	ND(>2.5)	(RDL 2.5, MDL 0.9)	1.9	Pblkl, J (RDL 2.9, MDL 1.1)	2.1	Pblkl, J (RDL 2.6, MDL 1.0)	1.6	Pblkl, J (RDL 2.5, MDL 0.9)	1.5	Pblkl, J (RDL 2.5, MDL 0.9)	2.0	Pblkl, J (RDL 2.5, MDL 0.9)			
E. Coli	200		MPN/100mL	ND (>200)		ND(>200)		ND (>200)		ND (>200)		ND (>200)		ND (>200)		ND (>200)				
Cations																				
total hardness	3.0	0.35	mg/L	14	J	45		65		43		41		96				190	190	190
Calcium	1.0	0.50	mg/L	4.3		13		24		11		11		27				61	62	62
Magnesium	1.0	0.50	mg/L	0.87		2.9		4.5		3.9		3.3		6.8				9	9.3	9.1
Anions																				
Nitrate as N	0.20	0.11	mg/L	0.43		0.95		0.74		1.5		1.2		0.61				4.9	4.8	4.8
Solids																				
TDS	10	5.5	mg/L	52		140		160		140		110		180				380	370	370
TSS	5	3	mg/L	22		51		29		46		24		26				ND (<5)	ND (<5)	**27**
Aggregate Organic Compounds																				
Total Organic Carbon	0.70	0.16	mg/L	23		20		22		24		22		28				ND (<.7)	ND (<.7)	0.27
Dissolved Organic Carbon	0.70	0.16	mg/L	19	N-TOCd	19	N-TOCd	23	N-TOCd	22	N-TOCd	20	N-TOCd	25	N-TOCd			0.44	0.41	0.53
Nutrients																				
Ammonia-Nitrogen	0.10	0.059	mg/L	0.56		0.2		0.36		ND(<.10)		0.11		0.32				ND(<.10)	ND(<.10)	ND(<.10)
Kjeldahl Nitrogen	0.20	0.13	mg/L	1.8		1.1		1.3		0.91		0.98		1.5				ND(<.20)	ND(<.10)	ND(<.20)
Ortho Phosphate Phosphorus	0.050	0.0028	mg/L	0.22		0.075		0.079		0.065		0.027	J	0.12				0.055	0.061	0.06
Total Phosphorus	0.05	0.01	mg/L	0.36		0.24		0.22		0.24		0.15	Pblkl	0.32				0.08	0.09	0.11
Metals and Metalloids-Total																				
Arsenic	1.0	0.08	µg/L	0.6	J	6.1		3.2		3.7		1.7		1.6				2.1	2.1	2.2
Cadmium	0.25	0.01	µg/L	0.04	J	0.14	J	0.05	J	0.1	J	0.1	J	0.08	J			0.01	0.01	0.03
Total Chromium	0.5	0.4	µg/L	1.6		3.9		2.9		2.1		1.4		2.3				2.4	2.2	2.6
Copper	0.5	0.04	µg/L	9.1		6.8		8.4		24		26		11				2.3	2.2	3.2
Iron	50	2.3	µg/L	730		3300		1400		2900		1500		1200				6.7	6.7	**200**
Lead	0.5	0.03	µg/L	1.2		2.8		1.2		2.1		0.8		1.5				0.4	0.6	0.6
Manganese	10	0.17	µg/L	25		82		37		78		44		55				0.21	0.17	**4.4**
Nickel	1.0	0.06	µg/L	2		1.5		1.6		2.9		3.7		3.7				1	1	1.4
Zinc	1.0	0.03	µg/L	35		12		12		19		15		34				20	20	**41**
Metals and Metalloids-Dissolved																				
Arsenic	1.0	0.08	µg/L	0.4	N_pFilt, J	5.2	N_pFilt	2.8	N_pFilt	2.8	N_pFilt, J	1.2	N_pFilt, J	1.3	N_pFilt, J			2	2.1	1.9
Cadmium	0.25	0.01	µg/L	0.03	N_pFilt, J, Pblkl	0.05	N_pFilt, J, Pblkl	0.04	N_pFilt, J, Pblkl	0.006	N_pFilt, J, Pblkl	0.06	N_pFilt, J, Pblkl	0.05	N_pFilt, J, Pblkl			0.02	0.02	0.02
Total Chromium	0.5	0.4	µg/L	0.7	N_pFilt	2.3	N_pFilt	1.9	N_pFilt	0.6	N_pFilt	0.7	N_pFilt	1.2	N_pFilt			2.8	2.8	2.9
Copper	0.5	0.04	µg/L	6.9	N_pFilt	4.7	N_pFilt	6.2	N_pFilt	19	N_pFilt	21	N_pFilt, J	8.9	N_pFilt			2	1.8	1.6
Iron	50	2.3	µg/L	47	N_pFilt, J, Pblkl	11	N_pFilt, J, Pblkl	17	N_pFilt, J, Pblkl	26	N_pFilt, J, Pblkl	25	N_pFilt, J, Pblkl	42	N_pFilt, J, Pblkl			ND (<50)	ND (<50)	ND (<50)
Lead	0.5	0.03	µg/L	0.2	N_pFilt, J, Pblkl	0.06	N_pFilt, J, Pblkl	0.07	N_pFilt, J, Pblkl	0.08	N_pFilt, J, Pblkl	0.04	N_pFilt, J, Pblkl	0.2	N_pFilt, J, Pblkl			0.2	0.2	0.06
Manganese	10	0.17	µg/L	11	N_pFilt	1.2	N_pFilt, J	2.1	N_pFilt, J	7.8	N_pFilt, J	11	N_pFilt	25	N_pFilt			ND (<10)	ND (<10)	ND (<10)
Nickel	1.0	0.06	µg/L	1.5	N_pFilt	0.7	N_pFilt, J	1	N_pFilt	1.9	N_pFilt	2.7	N_pFilt	3.0	N_pFilt			1.1	1	1
Zinc	1.0	0.03	µg/L	17	N_pFilt	1.5	N_pFilt	2.8	N_pFilt	7.5	N_pFilt	7.6	N_pFilt	17	N_pFilt			18	19	23

Flags

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N_pFilt = Sample filtered and preserved upon receipt to the laboratory

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Bid Abstract [redacted]

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Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

Item	No. & Description	Unit	Quantity	ENGINEER'S ESTIMATE Unit Bid	ENGINEER'S ESTIMATE Total Bid	ASR CONSTRUCTORS, INC. Unit Bid	ASR CONSTRUCTORS, INC. Total Bid	[redacted] Unit Bid	[redacted] Total Bid
1	MOBILIZATION	L.S.	1	$50,000.00	$50,000.00	$371,000.00	$371,000.00	$125,000.00	$125,000.00
2	WATER CONTROL	L.S.	1	$10,000.00	$10,000.00	$15,000.00	$15,000.00	$2,500.00	$2,500.00
3	TRAFFIC CONTROL	L.S.	1	$8,620.00	$8,620.00	$15,000.00	$15,000.00	$2,500.00	$2,500.00
4	CLEARING AND MISCELLANEOUS WORK	L.S.	1	$223,506.00	$223,506.00	$71,700.00	$71,700.00	$85,000.00	$85,000.00
5	EXTRA DIRECTED WORK	L.S.	1	$150,000.00	$150,000.00	$150,000.00	$150,000.00	$150,000.00	$150,000.00
6	EXCAVATION	C.Y.	7,230	$9.00	$65,070.00	$17.00	$122,910.00	$27.00	$195,210.00
7	TRENCH SAFETY SYSTEM	L.S.	1	$5,000.00	$5,000.00	$1,500.00	$1,500.00	$7,500.00	$7,500.00
8	CLASS "A" CONCRETE, 3'X3' CLEANOUT STRUCTURE AND SAMPLING VAULT	EACH	9	$3,150.00	$28,350.00	$1,280.00	$11,520.00	$2,000.00	$18,000.00
9	CLASS "A" CONCRETE, TRANSITION STRUCTURE NO. 3	EACH	3	$730.00	$2,190.00	$1,385.00	$4,155.00	$1,500.00	$4,500.00
10	CLASS "A" CONCRETE, UNDER SIDEWALK DRAIN	EACH	3	$1,675.00	$5,025.00	$1,280.00	$3,840.00	$2,600.00	$7,800.00
11	CLASS "A" CONCRETE, FOOTING AND CMU RAISED PLANTERS AND ENTRY SIGN WALLS	L.F.	158	$100.00	$15,800.00	$118.00	$18,644.00	$185.00	$29,230.00
12	CLASS "A" CONCRETE, CMU FLOW THROUGH PLANTER WALLS	L.F.	183	$50.00	$9,150.00	$70.00	$12,810.00	$280.00	$51,240.00
13	CLASS "A" CONCRETE, LANDSCAPE FILTER BASIN RETAINING WALL	C.Y.	48	$820.00	$39,360.00	$367.00	$17,616.00	$750.00	$36,000.00
14	CLASS "A" CONCRETE, SAMPLING BASIN STRUCTURE	EACH	1	$10,000.00	$10,000.00	$7,900.00	$7,900.00	$750.00	$750.00
15	CLASS "B" CONCRETE, CURB AND GUTTER (CD1, CD2, CD3, CD9)	L.F.	984	$34.50	$33,948.00	$9.00	$8,856.00	$25.00	$24,600.00
16	CLASS "B" CONCRETE, STANDARD CURB (CD4, CD5, CD6, CD7, CD8, CD24, CD26)	L.F.	3,500	$12.00	$42,000.00	$6.50	$22,750.00	$15.00	$52,500.00
17	CLASS "B" CONCRETE, DEEPENED CURB (CD10, CD11, CD12, CD30, CD31)	L.F.	5,250	$27.20	$142,800.00	$20.00	$105,000.00	$15.00	$78,750.00
18	CLASS "B" CONCRETE, MISCELLANEOUS	C.Y.	57	$540.00	$30,780.00	$228.00	$12,996.00	$300.00	$17,100.00
19	CLASS "B" CONCRETE, PLANTER AND BUILDING SLABS	C.Y.	24	$540.00	$12,960.00	$150.00	$3,600.00	$300.00	$7,200.00
20	INSTALL DECORATIVE CONCRETE FLATWORK	L.S.	1	$5,000.00	$5,000.00	$3,000.00	$3,000.00	$15,000.00	$15,000.00

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21 REINFORCED CONCRETE PIPE	L.F.	200	$86.50	$17,300.00	$119.00	$23,800.00	$121.00	$24,200.00
22 3" CLASS 2 AGGREGATE BASE DRIVEWAY AND ACCESS RAMP	C.Y.	10	$108.00	$1,080.00	$50.00	$500.00	$95.00	$950.00
23 PERVIOUS PAVERS OVER 2" #8 OVER 3" #57 OVER 13" #2 STONE	S.F.	25,400	$15.35	$389,890.00	$7.55	$191,770.00	$8.94	$227,076.00
24 PERVIOUS PAVERS OVER 2" #8 OVER 10-7/8" #57 STONE	S.F.	9,270	$14.40	$133,488.00	$6.70	$62,109.00	$8.94	$82,873.80
25 PERVIOUS PAVERS OVER 2" #8 OVER 3" #57 OVER 17" #2 STONE	S.F.	5,660	$16.05	$90,843.00	$8.70	$49,242.00	$8.94	$50,600.40
26 PERVIOUS PAVERS OVER 1" #8 OVER 4" #57 STONE	S.F.	1,184	$14.00	$16,576.00	$7.00	$8,288.00	$8.94	$10,584.96
27 8.5" PERVIOUS CONCRETE OVER 25" #57 STONE OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	2,360	$17.15	$40,474.00	$13.25	$31,270.00	$15.45	$36,462.00
28 8.5" PERVIOUS CONCRETE OVER 25" #57 STONE SURROUNDING 9" CLASS 2 AGGREGATE BASE AND FILTER FABRIC OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	2,090	$19.00	$39,710.00	$13.30	$27,797.00	$17.10	$35,739.00
29 5" POROUS ASPHALT OVER 25" #57 STONE OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	2,270	$15.20	$34,504.00	$7.00	$15,890.00	$6.00	$13,620.00
30 5" POROUS ASPHALT OVER 25" #57 STONE SURROUNDING 9" CLASS 2 AGGREGATE BASE AND FILTER FABRIC OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	1,700	$17.00	$28,900.00	$8.50	$14,450.00	$15.00	$25,500.00
31 4" AC OVER 6" CLASS 2 AGGREGATE BASE AND 4" AC OVER 11" CLASS 2 AGGREGATE BASE	S.F.	76,655	$3.40	$260,627.00	$2.75	$210,801.25	$2.25	$172,473.75
32 VARIABLE DEPTH AC OVERLAY	TONS	31	$72.00	$2,232.00	$80.00	$2,480.00	$210.00	$6,510.00
33 GRIND EXISTING AC PAVEMENT	S.F.	720	$3.00	$2,160.00	$2.00	$1,440.00	$4.00	$2,880.00
34 SLURRY SEAL	S.F.	35,800	$0.10	$3,580.00	$0.33	$11,814.00	$0.54	$19,332.00
35 BOLLARD	EACH	260	$375.00	$97,500.00	$135.00	$35,100.00	$110.00	$28,600.00

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36 4" PVC PIPE	L.F.	78	$18.00	$1,404.00	$32.00	$2,496.00	$15.00	$1,170.00
37 6" PVC PIPE	L.F.	2,126	$20.00	$42,520.00	$35.00	$74,410.00	$10.00	$21,260.00
38 8" PVC PIPE	L.F.	369	$30.00	$11,070.00	$36.50	$13,468.50	$15.00	$5,535.00
39 12" PVC PIPE	L.F.	314	$60.00	$18,840.00	$42.00	$13,188.00	$25.00	$7,850.00
40 18" PVC PIPE	L.F.	33	$113.00	$3,729.00	$49.00	$1,617.00	$50.00	$1,650.00
41 10" WIDE SLOTTED DRAIN	L.F.	177	$75.00	$13,275.00	$35.00	$6,195.00	$40.00	$7,080.00
42 PRECAST CONCRETE FLOW DETECTION CATCH BASIN	EACH	3	$600.00	$1,800.00	$2,400.00	$7,200.00	$2,150.00	$6,450.00
43 9"X9" PLASTIC CATCH BASIN	EACH	7	$500.00	$3,500.00	$126.00	$882.00	$650.00	$4,550.00
44 18"X18" PRECAST CONCRETE CATCH BASIN	EACH	2	$800.00	$1,600.00	$2,600.00	$5,200.00	$1,250.00	$2,500.00
45 24"X24" PRECAST CONCRETE CATCH BASIN	EACH	1	$1,000.00	$1,000.00	$3,500.00	$3,500.00	$1,250.00	$1,250.00
46 36"X36" PRECAST CONCRETE CATCH BASIN	EACH	5	$1,200.00	$6,000.00	$4,900.00	$24,500.00	$1,250.00	$6,250.00
47 GALVANIZED STEEL CATCH BASIN LID	EACH	1	$500.00	$500.00	$650.00	$650.00	$950.00	$950.00
48 PVC PIPE STORMWATER CLEANOUT	EACH	23	$750.00	$17,250.00	$190.00	$4,370.00	$450.00	$10,350.00
49 PRECAST CONCRETE HEADWALL FOR 8" PIPE	EACH	1	$500.00	$500.00	$2,000.00	$2,000.00	$1,000.00	$1,000.00
50 3" ELECTRICAL CONDUIT FROM PREFABRICATED BUILDING TO SAMPLING BASIN STRUCTURE	L.F.	530	$10.00	$5,300.00	$15.00	$7,950.00	$8.00	$4,240.00
51 NEW WHEEL STOPS	EACH	95	$50.00	$4,750.00	$35.00	$3,325.00	$60.00	$5,700.00
52 SIGNS INCLUDING POST AND FOOTING	EACH	2	$500.00	$1,000.00	$200.00	$400.00	$250.00	$500.00
53 PREFABRICATED 12'X22' BUILDING AND 2" ELECTRICAL CONDUIT FROM PULL BOX TO PREFABRICATED BUILDING	L.S.	1	$10,000.00	$10,000.00	$10,600.00	$10,600.00	$18,000.00	$18,000.00
54 3.5' HIGH METAL RAILING	L.F.	55	$25.00	$1,375.00	$80.00	$4,400.00	$100.00	$5,500.00
55 CONNECTION TO EXISTING BUILDING ROOF DOWNDRAINS	EACH	3	$1,000.00	$3,000.00	$600.00	$1,800.00	$500.00	$1,500.00
56 ENHANCED GRASS SWALE	L.S.	1	$7,267.00	$7,267.00	$7,000.00	$7,000.00	$10,000.00	$10,000.00
57 ADJUST MANHOLE AND VAULT TO GRADE	EACH	9	$650.00	$5,850.00	$825.00	$7,425.00	$500.00	$4,500.00

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58 ADJUST VALVE AND CLEANOUT TO GRADE	EACH	13	$450.00	$5,850.00	$125.00	$1,625.00	$150.00	$1,950.00
59 COBBLE FILLED TRENCH	L.F.	430	$10.00	$4,300.00	$17.00	$7,310.00	$10.00	$4,300.00
60 4'X4' #2 STONE INFILTRATION TRENCH IN LAKE SMITHHAMMER	L.F.	220	$36.00	$7,920.00	$39.00	$8,580.00	$45.00	$9,900.00
61 #57 STONE IN LANDSCAPE FILTER BASIN AND FLOW THROUGH PLANTERS	C.Y.	31	$60.00	$1,860.00	$74.00	$2,294.00	$65.00	$2,015.00
62 MIRAFI FW402 FILTER FABRIC	S.F.	7,570	$0.55	$4,163.50	$0.40	$3,028.00	$1.00	$7,570.00
63 MIRAFI NT100 IMPERMEABLE BARRIER	S.F.	13,330	$0.60	$7,998.00	$0.85	$11,330.50	$1.00	$13,330.00
64 #2 STONE ENERGY DISSIPATERS	C.Y.	1	$60.00	$60.00	$100.00	$100.00	$300.00	$300.00
65 DUST ABATEMENT	L.S.	1	$10,000.00	$10,000.00	$12,000.00	$12,000.00	$8,000.00	$8,000.00
66 STORMWATER AND NON-STORMWATER POLLUTION CONTROL	L.S.	1	$5,000.00	$5,000.00	$3,000.00	$3,000.00	$5,500.00	$5,500.00
67 NON-STORMWATER DISCHARGE OR DEWATERING	L.S.	1	$2,000.00	$2,000.00	$3,000.00	$3,000.00	$4,500.00	$4,500.00
68 REMOVAL AND REPLACEMENT OF EXISTING UTILITIES AT NEW LANDSCAPE FILTER BASIN	L.F.	360	$38.00	$13,680.00	$9.75	$3,510.00	$25.00	$9,000.00
69 REMOVAL AND RELOCATION OF EXISTING IRRIGATION DOUBLE CHECK VALVE AND REMOVAL AND REPLACEMENT OF EXISTING 4-INCH WATERLINE	L.S.	1	$10,000.00	$10,000.00	$4,630.00	$4,630.00	$10,000.00	$10,000.00
70 FILTRATION SOIL MIXTURE	C.Y.	90	$75.00	$6,750.00	$60.00	$5,400.00	$65.00	$5,850.00
71 IRRIGATION SYSTEM	L.S.	1	$259,900.00	$259,900.00	$168,000.00	$168,000.00	$275,000.00	$275,000.00
72 SOIL TESTING AND SOIL PREPARATION	S.F.	182,100	$0.28	$50,988.00	$0.14	$25,494.00	$0.24	$43,704.00
73 MOW CURBING	L.F.	2,875	$11.00	$31,625.00	$3.50	$10,062.50	$9.00	$25,875.00
74 WOOD CHIPS	S.F.	145,600	$0.36	$52,416.00	$0.20	$29,120.00	$0.31	$45,136.00
75 DECOMPOSED GRANITE	S.F.	2,080	$3.50	$7,280.00	$1.00	$2,080.00	$2.95	$6,136.00
76 CRUSHED ROCK	S.F.	2,100	$3.25	$6,825.00	$1.00	$2,100.00	$2.50	$5,250.00
77 DRIVABLE GRASS	S.F.	785	$17.25	$13,541.25	$3.85	$3,022.25	$12.00	$9,420.00
78 SYNTHETIC TURF	S.F.	315	$15.00	$4,725.00	$4.75	$1,496.25	$18.00	$5,670.00
79 SOD	S.F.	36,500	$0.85	$31,025.00	$0.45	$16,425.00	$1.25	$45,625.00

Project Name: **L.I.D. Testing & Demonstration Facility, Parking Lot Renovation 2010, and Water Efficient Landscape Conversion**

Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

Item No. & Description	Unit	Quantity	ENGINEER'S ESTIMATE Unit Bid	ENGINEER'S ESTIMATE Total Bid	ASR CONSTRUCTORS, INC. Unit Bid	ASR CONSTRUCTORS, INC. Total Bid	YAKAR Unit Bid	YAKAR Total Bid
80 FLATS	EACH	675	$27.00	$18,225.00	$33.00	$22,275.00	$12.00	$8,100.00
81 1-GALLON	EACH	2,800	$6.25	$17,500.00	$5.20	$14,560.00	$5.00	$14,000.00
82 2-GALLON	EACH	98	$11.00	$1,078.00	$14.60	$1,430.80	$10.00	$980.00
83 5-GALLON	EACH	1,575	$15.75	$24,806.25	$11.35	$17,876.25	$13.00	$20,475.00
84 15-GALLON	EACH	18	$150.00	$2,700.00	$75.00	$1,350.00	$85.00	$1,530.00
85 15-GALLON CITRUS	EACH	62	$88.00	$5,456.00	$106.50	$6,603.00	$80.00	$4,960.00
86 24" BOX	EACH	138	$235.00	$32,430.00	$174.00	$24,012.00	$195.00	$26,910.00
87 36" BOX	EACH	7	$610.00	$4,270.00	$610.00	$4,270.00	$350.00	$2,450.00
88 48" BOX	EACH	1	$1,375.00	$1,375.00	$1,050.00	$1,050.00	$800.00	$800.00
89 6' BROWN TRUNK PALM	EACH	2	$690.00	$1,380.00	$900.00	$1,800.00	$750.00	$1,500.00
90 TREE GRATE	EACH	2	$1,600.00	$3,200.00	$1,000.00	$2,000.00	$1,238.00	$2,476.00
91 PICNIC TABLE	EACH	5	$1,500.00	$7,500.00	$1,250.00	$6,250.00	$1,457.00	$7,285.00
92 WASTE CONTAINER	EACH	9	$615.00	$5,535.00	$650.00	$5,850.00	$835.00	$7,515.00
93 FOUNTAIN	EACH	1	$2,100.00	$2,100.00	$3,000.00	$3,000.00	$1,450.00	$1,450.00
94 FLAG POLE	EACH	2	$6,950.00	$13,900.00	$3,850.00	$7,700.00	$4,500.00	$9,000.00
95 CONCRETE POT #13	EACH	4	$875.00	$3,500.00	$900.00	$3,600.00	$925.00	$3,700.00
96 CONCRETE POT #13A	EACH	8	$1,100.00	$8,800.00	$900.00	$7,200.00	$1,065.00	$8,520.00
97 CONCRETE POT #13B	EACH	4	$775.00	$3,100.00	$600.00	$2,400.00	$475.00	$1,900.00
98 CONCRETE BENCH #10	EACH	8	$2,450.00	$19,600.00	$600.00	$4,800.00	$675.00	$5,400.00
99 CONCRETE BENCH #15	EACH	6	$650.00	$3,900.00	$600.00	$3,600.00	$675.00	$4,050.00
100 LANDSCAPE MAINTENANCE	L.S.	1	$7,200.00	$7,200.00	$6,000.00	$6,000.00	$3,000.00	$3,000.00
101 ELECTRICAL LIGHTING FIXTURE A	EACH	24	$810.00	$19,440.00	$940.00	$22,560.00	$935.00	$22,440.00
102 ELECTRICAL LIGHTING FIXTURE B	EACH	2	$1,100.00	$2,200.00	$980.00	$1,960.00	$5,000.00	$10,000.00
103 ELECTRICAL LIGHTING FIXTURE C	EACH	5	$1,650.00	$8,250.00	$2,040.00	$10,200.00	$5,000.00	$25,000.00
104 ELECTRICAL LIGHTING FIXTURE D	EACH	9	$2,850.00	$25,650.00	$2,000.00	$18,000.00	$2,870.00	$25,830.00
105 ELECTRICAL LIGHTING FIXTURE E	EACH	4	$550.00	$2,200.00	$700.00	$2,800.00	$750.00	$3,000.00
106 ELECTRICAL CONDUIT AND WIRE	L.F.	4,450	$4.55	$20,247.50	$9.80	$43,610.00	$7.00	$31,150.00
				$3,013,402.50		**$2,439,489.30**		**$2,573,018.91**

Project Name: **L.I.D. Testing & Demonstration Facility, Parking Lot Renovation 2010, and Water Efficient Landscape Conversion**

Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

Item	No. & Description	Unit	Quantity	DELMAC CONSTRUCTION & DEVELOPMENT, INC. Unit Bid	DELMAC CONSTRUCTION & DEVELOPMENT, INC. Total Bid	BRAUGHTON CONSTRUCTION, INC. Unit Bid	BRAUGHTON CONSTRUCTION, INC. Total Bid	ENVIRONMENTAL CONSTRUCTION, INC. Unit Bid	ENVIRONMENTAL CONSTRUCTION, INC. Total Bid
1	MOBILIZATION	L.S.	1	$133,000.00	$133,000.00	$183,171.00	$183,171.00	$34,000.00	$34,000.00
2	WATER CONTROL	L.S.	1	$15,000.00	$15,000.00	$323.00	$323.00	$2,000.00	$2,000.00
3	TRAFFIC CONTROL	L.S.	1	$40,000.00	$40,000.00	$753.00	$753.00	$7,000.00	$7,000.00
4	CLEARING AND MISCELLANEOUS WORK	L.S.	1	$20,000.00	$20,000.00	$16,146.00	$16,146.00	$315,878.00	$315,878.00
5	EXTRA DIRECTED WORK	L.S.	1	$150,000.00	$150,000.00	$150,000.00	$150,000.00	$150,000.00	$150,000.00
6	EXCAVATION	C.Y.	7,230	$8.00	$57,840.00	$34.45	$249,073.50	$18.16	$131,296.80
7	TRENCH SAFETY SYSTEM	L.S.	1	$10,000.00	$10,000.00	$538.00	$538.00	$500.00	$500.00
8	CLASS "A" CONCRETE, 3'X3' CLEANOUT STRUCTURE AND SAMPLING VAULT	EACH	9	$2,000.00	$18,000.00	$1,534.00	$13,806.00	$1,750.00	$15,750.00
9	CLASS "A" CONCRETE, TRANSITION STRUCTURE NO. 3	EACH	3	$2,500.00	$7,500.00	$500.00	$1,500.00	$2,560.00	$7,680.00
10	CLASS "A" CONCRETE, UNDER SIDEWALK DRAIN	EACH	3	$600.00	$1,800.00	$2,583.00	$7,749.00	$720.00	$2,160.00
11	CLASS "A" CONCRETE, FOOTING AND CMU RAISED PLANTERS AND ENTRY SIGN WALLS	L.F.	158	$130.00	$20,540.00	$81.81	$12,925.98	$98.00	$15,484.00
12	CLASS "A" CONCRETE, CMU FLOW THROUGH PLANTER WALLS	L.F.	183	$90.00	$16,470.00	$81.81	$14,971.23	$117.50	$21,502.50
13	CLASS "A" CONCRETE, LANDSCAPE FILTER BASIN RETAINING WALL	C.Y.	48	$350.00	$16,800.00	$112.13	$5,382.24	$805.00	$38,640.00
14	CLASS "A" CONCRETE, SAMPLING BASIN STRUCTURE	EACH	1	$40,000.00	$40,000.00	$1,184.00	$1,184.00	$15,601.00	$15,601.00
15	CLASS "B" CONCRETE, CURB AND GUTTER (CD1, CD2, CD3, CD9)	L.F.	984	$22.00	$21,648.00	$20.66	$20,329.44	$28.50	$28,044.00
16	CLASS "B" CONCRETE, STANDARD CURB (CD4, CD5, CD6, CD7, CD8, CD24, CD26)	L.F.	3,500	$17.00	$59,500.00	$16.61	$58,135.00	$21.00	$73,500.00
17	CLASS "B" CONCRETE, DEEPENED CURB (CD10, CD11, CD12, CD30, CD31)	L.F.	5,250	$50.00	$262,500.00	$48.77	$256,042.50	$28.60	$150,150.00
18	CLASS "B" CONCRETE, MISCELLANEOUS	C.Y.	57	$1,065.00	$60,705.00	$1,042.18	$59,404.26	$300.00	$17,100.00
19	CLASS "B" CONCRETE, PLANTER AND BUILDING SLABS	C.Y.	24	$250.00	$6,000.00	$112.13	$2,691.12	$486.00	$11,664.00
20	INSTALL DECORATIVE CONCRETE FLATWORK	L.S.	1	$45,000.00	$45,000.00	$3,767.00	$3,767.00	$1,500.00	$1,500.00

Project Name: **L.I.D. Testing & Demonstration Facility, Parking Lot Renovation 2010, and Water Efficient Landscape Conversion**

Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

Item No. & Description	*Unit*	*Quantity*	DELMAC CONSTRUCTION & DEVELOPMENT, INC. *Unit Bid*	DELMAC *Total Bid*	BRAUGHTON CONSTRUCTION, INC. *Unit Bid*	BRAUGHTON *Total Bid*	ENVIRONMENTAL CONSTRUCTION, INC. *Unit Bid*	ENVIRONMENTAL *Total Bid*
21 REINFORCED CONCRETE PIPE	L.F.	200	$82.00	$16,400.00	$43.06	$8,612.00	$45.00	$9,000.00
22 3" CLASS 2 AGGREGATE BASE DRIVEWAY AND ACCESS RAMP	C.Y.	10	$30.00	$300.00	$107.64	$1,076.40	$40.50	$405.00
23 PERVIOUS PAVERS OVER 2" #8 OVER 3" #57 OVER 13" #2 STONE	S.F.	25,400	$7.00	$177,800.00	$7.69	$195,326.00	$9.00	$228,600.00
24 PERVIOUS PAVERS OVER 2" #8 OVER 10-7/8" #57 STONE	S.F.	9,270	$7.00	$64,890.00	$6.72	$62,294.40	$8.10	$75,087.00
25 PERVIOUS PAVERS OVER 2" #8 OVER 3" #57 OVER 17" #2 STONE	S.F.	5,660	$7.00	$39,620.00	$8.71	$49,298.60	$6.44	$36,450.40
26 PERVIOUS PAVERS OVER 1" #8 OVER 4" #57 STONE	S.F.	1,184	$7.00	$8,288.00	$6.34	$7,506.56	$6.70	$7,932.80
27 8.5" PERVIOUS CONCRETE OVER 25" #57 STONE OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	2,360	$20.00	$47,200.00	$19.27	$45,477.20	$14.00	$33,040.00
28 8.5" PERVIOUS CONCRETE OVER 25" #57 STONE SURROUNDING 9" CLASS 2 AGGREGATE BASE AND FILTER FABRIC OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	2,090	$54.00	$112,860.00	$57.44	$120,049.60	$15.75	$32,917.50
29 5" POROUS ASPHALT OVER 25" #57 STONE OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	2,270	$5.00	$11,350.00	$5.77	$13,097.90	$18.65	$42,335.50
30 5" POROUS ASPHALT OVER 25" #57 STONE SURROUNDING 9" CLASS 2 AGGREGATE BASE AND FILTER FABRIC OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	1,700	$10.00	$17,000.00	$10.29	$17,493.00	$53.70	$91,290.00
31 4" AC OVER 6" CLASS 2 AGGREGATE BASE AND 4" AC OVER 11" CLASS 2 AGGREGATE BASE	S.F.	76,655	$2.00	$153,310.00	$2.55	$195,470.25	$2.70	$206,968.50
32 VARIABLE DEPTH AC OVERLAY	TONS	31	$90.00	$2,790.00	$121.25	$3,758.75	$122.76	$3,805.56
33 GRIND EXISTING AC PAVEMENT	S.F.	720	$3.75	$2,700.00	$5.22	$3,758.40	$3.85	$2,772.00
34 SLURRY SEAL	S.F.	35,800	$0.25	$8,950.00	$0.50	$17,900.00	$0.37	$13,389.20
35 BOLLARD	EACH	260	$225.00	$58,500.00	$161.46	$41,979.60	$165.00	$42,900.00

Project Name: **L.I.D. Testing & Demonstration Facility, Parking Lot Renovation 2010, and Water Efficient Landscape Conversion**

Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

Item No. & Description	Unit	Quantity	DELMAC CONSTRUCTION & DEVELOPMENT, INC. Unit Bid	DELMAC CONSTRUCTION & DEVELOPMENT, INC. Total Bid	BRAUGHTON CONSTRUCTION, INC. Unit Bid	BRAUGHTON CONSTRUCTION, INC. Total Bid	ENVIRONMENTAL CONSTRUCTION, INC. Unit Bid	ENVIRONMENTAL CONSTRUCTION, INC. Total Bid
36 4" PVC PIPE	L.F.	78	$10.00	$780.00	$32.29	$2,518.62	$15.00	$1,170.00
37 6" PVC PIPE	L.F.	2,126	$12.00	$25,512.00	$37.67	$80,086.42	$16.60	$35,291.60
38 8" PVC PIPE	L.F.	369	$16.00	$5,904.00	$43.06	$15,889.14	$25.50	$9,409.50
39 12" PVC PIPE	L.F.	314	$25.00	$7,850.00	$48.44	$15,210.16	$36.50	$11,461.00
40 18" PVC PIPE	L.F.	33	$60.00	$1,980.00	$53.82	$1,776.06	$50.00	$1,650.00
41 10" WIDE SLOTTED DRAIN	L.F.	177	$30.00	$5,310.00	$188.37	$33,341.49	$300.00	$53,100.00
42 PRECAST CONCRETE FLOW DETECTION CATCH BASIN	EACH	3	$1,500.00	$4,500.00	$5,382.10	$16,146.30	$4,500.00	$13,500.00
43 9"X9" PLASTIC CATCH BASIN	EACH	7	$300.00	$2,100.00	$80.73	$565.11	$100.00	$700.00
44 18"X18" PRECAST CONCRETE CATCH BASIN	EACH	2	$1,000.00	$2,000.00	$1,345.52	$2,691.04	$800.00	$1,600.00
45 24"X24" PRECAST CONCRETE CATCH BASIN	EACH	1	$1,600.00	$1,600.00	$1,883.73	$1,883.73	$1,150.00	$1,150.00
46 36"X36" PRECAST CONCRETE CATCH BASIN	EACH	5	$2,500.00	$12,500.00	$3,229.26	$16,146.30	$2,700.00	$13,500.00
47 GALVANIZED STEEL CATCH BASIN LID	EACH	1	$400.00	$400.00	$2,045.20	$2,045.20	$1,500.00	$1,500.00
48 PVC PIPE STORMWATER CLEANOUT	EACH	23	$300.00	$6,900.00	$646.00	$14,858.00	$250.00	$5,750.00
49 PRECAST CONCRETE HEADWALL FOR 8" PIPE	EACH	1	$500.00	$500.00	$3,229.26	$3,229.26	$1,000.00	$1,000.00
50 3" ELECTRICAL CONDUIT FROM PREFABRICATED BUILDING TO SAMPLING BASIN STRUCTURE	L.F.	530	$10.00	$5,300.00	$16.15	$8,559.50	$16.50	$8,745.00
51 NEW WHEEL STOPS	EACH	95	$30.00	$2,850.00	$69.97	$6,647.15	$49.50	$4,702.50
52 SIGNS INCLUDING POST AND FOOTING	EACH	2	$300.00	$600.00	$177.61	$355.22	$192.50	$385.00
53 PREFABRICATED 12'X22' BUILDING AND 2" ELECTRICAL CONDUIT FROM PULL BOX TO PREFABRICATED BUILDING	L.S.	1	$50,000.00	$50,000.00	$2,153.00	$2,153.00	$20,477.00	$20,477.00
54 3.5' HIGH METAL RAILING	L.F.	55	$97.00	$5,335.00	$173.30	$9,531.50	$177.10	$9,740.50
55 CONNECTION TO EXISTING BUILDING ROOF DOWNDRAINS	EACH	3	$300.00	$900.00	$358.81	$1,076.43	$100.00	$300.00
56 ENHANCED GRASS SWALE	L.S.	1	$50,000.00	$50,000.00	$3,767.00	$3,767.00	$3,834.00	$3,834.00
57 ADJUST MANHOLE AND VAULT TO GRADE	EACH	9	$400.00	$3,600.00	$484.39	$4,359.51	$250.00	$2,250.00

Project Name: **L.I.D. Testing & Demonstration Facility, Parking Lot Renovation 2010, and Water Efficient Landscape Conversion**

Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

			DELMAC CONSTRUCTION & DEVELOPMENT, INC.		BRAUGHTON CONSTRUCTION, INC.		ENVIRONMENTAL CONSTRUCTION, INC.	
Item No. & Description	*Unit*	*Quantity*	*Unit Bid*	*Total Bid*	*Unit Bid*	*Total Bid*	*Unit Bid*	*Total Bid*
58 ADJUST VALVE AND CLEANOUT TO GRADE	EACH	13	$500.00	$6,500.00	$26.91	$349.83	$200.00	$2,600.00
59 COBBLE FILLED TRENCH	L.F.	430	$6.00	$2,580.00	$9.69	$4,166.70	$8.00	$3,440.00
60 4'X4' #2 STONE INFILTRATION TRENCH IN LAKE SMITHHAMMER	L.F.	220	$30.00	$6,600.00	$75.35	$16,577.00	$54.75	$12,045.00
61 #57 STONE IN LANDSCAPE FILTER BASIN AND FLOW THROUGH PLANTERS	C.Y.	31	$50.00	$1,550.00	$94.72	$2,936.32	$42.00	$1,302.00
62 MIRAFI FW402 FILTER FABRIC	S.F.	7,570	$0.30	$2,271.00	$0.30	$2,271.00	$0.50	$3,785.00
63 MIRAFI NT100 IMPERMEABLE BARRIER	S.F.	13,330	$1.50	$19,995.00	$0.71	$9,464.30	$1.30	$17,329.00
64 #2 STONE ENERGY DISSIPATERS	C.Y.	1	$50.00	$50.00	$108.00	$108.00	$60.00	$60.00
65 DUST ABATEMENT	L.S.	1	$20,000.00	$20,000.00	$8,692.00	$8,692.00	$4,000.00	$4,000.00
66 STORMWATER AND NON-STORMWATER POLLUTION CONTROL	L.S.	1	$5,000.00	$5,000.00	$9,715.00	$9,715.00	$2,000.00	$2,000.00
67 NON-STORMWATER DISCHARGE OR DEWATERING	L.S.	1	$5,000.00	$5,000.00	$538.00	$538.00	$2,000.00	$2,000.00
68 REMOVAL AND REPLACEMENT OF EXISTING UTILITIES AT NEW LANDSCAPE FILTER BASIN	L.F.	360	$25.00	$9,000.00	$37.67	$13,561.20	$12.00	$4,320.00
69 REMOVAL AND RELOCATION OF EXISTING IRRIGATION DOUBLE CHECK VALVE AND REMOVAL AND REPLACEMENT OF EXISTING 4-INCH WATERLINE	L.S.	1	$4,000.00	$4,000.00	$16,146.00	$16,146.00	$4,000.00	$4,000.00
70 FILTRATION SOIL MIXTURE	C.Y.	90	$20.00	$1,800.00	$61.36	$5,522.40	$60.00	$5,400.00
71 IRRIGATION SYSTEM	L.S.	1	$253,000.00	$253,000.00	$220,414.00	$220,414.00	$282,000.00	$282,000.00
72 SOIL TESTING AND SOIL PREPARATION	S.F.	182,100	$0.14	$25,494.00	$0.27	$49,167.00	$0.22	$40,062.00
73 MOW CURBING	L.F.	2,875	$4.40	$12,650.00	$5.88	$16,905.00	$13.00	$37,375.00
74 WOOD CHIPS	S.F.	145,600	$0.43	$62,608.00	$0.35	$50,960.00	$0.40	$58,240.00
75 DECOMPOSED GRANITE	S.F.	2,080	$1.60	$3,328.00	$1.65	$3,432.00	$1.85	$3,848.00
76 CRUSHED ROCK	S.F.	2,100	$2.37	$4,977.00	$2.32	$4,872.00	$0.50	$1,050.00
77 DRIVABLE GRASS	S.F.	785	$5.41	$4,246.85	$8.46	$6,641.10	$9.60	$7,536.00
78 SYNTHETIC TURF	S.F.	315	$13.20	$4,158.00	$30.24	$9,525.60	$16.00	$5,040.00
79 SOD	S.F.	36,500	$0.53	$19,345.00	$0.54	$19,710.00	$0.65	$23,725.00

Project Name: **L.I.D. Testing & Demonstration Facility, Parking Lot Renovation 2010, and Water Efficient Landscape Conversion**

Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

			DELMAC CONSTRUCTION & DEVELOPMENT, INC.		BRAUGHTON CONSTRUCTION, INC.		ENVIRONMENTAL CONSTRUCTION, INC.	
Item No. & Description	*Unit*	*Quantity*	*Unit Bid*	*Total Bid*	*Unit Bid*	*Total Bid*	*Unit Bid*	*Total Bid*
80 FLATS	EACH	675	$17.60	$11,880.00	$22.55	$15,221.25	$17.00	$11,475.00
81 1-GALLON	EACH	2,800	$5.23	$14,644.00	$6.65	$18,620.00	$6.25	$17,500.00
82 2-GALLON	EACH	98	$13.20	$1,293.60	$14.88	$1,458.24	$16.00	$1,568.00
83 5-GALLON	EACH	1,575	$20.90	$32,917.50	$18.00	$28,350.00	$14.00	$22,050.00
84 15-GALLON	EACH	18	$71.50	$1,287.00	$99.45	$1,790.10	$80.00	$1,440.00
85 15-GALLON CITRUS	EACH	62	$88.00	$5,456.00	$172.11	$10,670.82	$125.00	$7,750.00
86 24" BOX	EACH	138	$137.50	$18,975.00	$247.38	$34,138.44	$195.00	$26,910.00
87 36" BOX	EACH	7	$385.00	$2,695.00	$551.13	$3,857.91	$475.00	$3,325.00
88 48" BOX	EACH	1	$1,210.00	$1,210.00	$1,195.90	$1,195.90	$1,050.00	$1,050.00
89 6' BROWN TRUNK PALM	EACH	2	$528.00	$1,056.00	$837.45	$1,674.90	$1,000.00	$2,000.00
90 TREE GRATE	EACH	2	$1,300.00	$2,600.00	$3,286.85	$6,573.70	$1,320.00	$2,640.00
91 PICNIC TABLE	EACH	5	$1,143.00	$5,715.00	$1,612.69	$8,063.45	$1,867.50	$9,337.50
92 WASTE CONTAINER	EACH	9	$576.00	$5,184.00	$833.03	$7,497.27	$859.50	$7,735.50
93 FOUNTAIN	EACH	1	$3,000.00	$3,000.00	$2,080.73	$2,080.73	$1,957.50	$1,957.50
94 FLAG POLE	EACH	2	$2,143.00	$4,286.00	$4,984.36	$9,968.72	$5,244.00	$10,488.00
95 CONCRETE POT #13	EACH	4	$758.00	$3,032.00	$1,076.69	$4,306.76	$1,129.50	$4,518.00
96 CONCRETE POT #13A	EACH	8	$800.00	$6,400.00	$1,127.95	$9,023.60	$1,189.50	$9,516.00
97 CONCRETE POT #13B	EACH	4	$325.00	$1,300.00	$509.95	$2,039.80	$484.50	$1,938.00
98 CONCRETE BENCH #10	EACH	8	$448.00	$3,584.00	$695.64	$5,565.12	$675.00	$5,400.00
99 CONCRETE BENCH #15	EACH	6	$448.00	$2,688.00	$709.00	$4,254.00	$675.00	$4,050.00
100 LANDSCAPE MAINTENANCE	L.S.	1	$6,010.00	$6,010.00	$4,938.00	$4,938.00	$4,000.00	$4,000.00
101 ELECTRICAL LIGHTING FIXTURE A	EACH	24	$1,089.00	$26,136.00	$1,237.88	$29,709.12	$1,265.00	$30,360.00
102 ELECTRICAL LIGHTING FIXTURE B	EACH	2	$1,100.00	$2,200.00	$1,237.88	$2,475.76	$1,265.00	$2,530.00
103 ELECTRICAL LIGHTING FIXTURE C	EACH	5	$3,245.00	$16,225.00	$2,755.63	$13,778.15	$2,816.00	$14,080.00
104 ELECTRICAL LIGHTING FIXTURE D	EACH	9	$3,245.00	$29,205.00	$2,992.45	$26,932.05	$3,058.00	$27,522.00
105 ELECTRICAL LIGHTING FIXTURE E	EACH	4	$1,100.00	$4,400.00	$1,200.21	$4,800.84	$1,226.50	$4,906.00
106 ELECTRICAL CONDUIT AND WIRE	L.F.	4,450	$10.00	$44,500.00	$13.00	$57,850.00	$13.20	$58,740.00
				$2,652,713.95		**$2,872,336.15**		**$2,883,503.36**

Project Name: **L.I.D. Testing & Demonstration Facility, Parking Lot Renovation 2010, and Water Efficient Landscape Conversion**

Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

			RIVERSIDE CONSTRUCTION		STRONGHOLD ENGINEERING, INC.		4-CON ENGINEERING, INC.	
Item No. & Description	*Unit*	*Quantity*	*Unit Bid*	*Total Bid*	*Unit Bid*	*Total Bid*	*Unit Bid*	*Total Bid*
1 MOBILIZATION	L.S.	1	$170,000.00	$170,000.00	$150,000.00	$150,000.00	$300,000.00	$300,000.00
2 WATER CONTROL	L.S.	1	$2,500.00	$2,500.00	$10,000.00	$10,000.00	$1,500.00	$1,500.00
3 TRAFFIC CONTROL	L.S.	1	$35,000.00	$35,000.00	$20,000.00	$20,000.00	$10,000.00	$10,000.00
4 CLEARING AND MISCELLANEOUS WORK	L.S.	1	$265,000.00	$265,000.00	$281,000.00	$281,000.00	$120,000.00	$120,000.00
5 EXTRA DIRECTED WORK	L.S.	1	$150,000.00	$150,000.00	$150,000.00	$150,000.00	$150,000.00	$150,000.00
6 EXCAVATION	C.Y.	7,230	$20.00	$144,600.00	$40.00	$289,200.00	$52.00	$375,960.00
7 TRENCH SAFETY SYSTEM	L.S.	1	$500.00	$500.00	$8,500.00	$8,500.00	$2,000.00	$2,000.00
8 CLASS "A" CONCRETE, 3'X3' CLEANOUT STRUCTURE AND SAMPLING VAULT	EACH	9	$3,500.00	$31,500.00	$5,900.00	$53,100.00	$2,000.00	$18,000.00
9 CLASS "A" CONCRETE, TRANSITION STRUCTURE NO. 3	EACH	3	$1,200.00	$3,600.00	$750.00	$2,250.00	$2,000.00	$6,000.00
10 CLASS "A" CONCRETE, UNDER SIDEWALK DRAIN	EACH	3	$1,200.00	$3,600.00	$3,200.00	$9,600.00	$2,500.00	$7,500.00
11 CLASS "A" CONCRETE, FOOTING AND CMU RAISED PLANTERS AND ENTRY SIGN WALLS	L.F.	158	$110.00	$17,380.00	$160.00	$25,280.00	$175.00	$27,650.00
12 CLASS "A" CONCRETE, CMU FLOW THROUGH PLANTER WALLS	L.F.	183	$95.00	$17,385.00	$137.00	$25,071.00	$175.00	$32,025.00
13 CLASS "A" CONCRETE, LANDSCAPE FILTER BASIN RETAINING WALL	C.Y.	48	$650.00	$31,200.00	$583.00	$27,984.00	$425.00	$20,400.00
14 CLASS "A" CONCRETE, SAMPLING BASIN STRUCTURE	EACH	1	$15,000.00	$15,000.00	$4,300.00	$4,300.00	$4,500.00	$4,500.00
15 CLASS "B" CONCRETE, CURB AND GUTTER (CD1, CD2, CD3, CD9)	L.F.	984	$17.00	$16,728.00	$33.00	$32,472.00	$25.00	$24,600.00
16 CLASS "B" CONCRETE, STANDARD CURB (CD4, CD5, CD6, CD7, CD8, CD24, CD26)	L.F.	3,500	$15.00	$52,500.00	$18.00	$63,000.00	$12.00	$42,000.00
17 CLASS "B" CONCRETE, DEEPENED CURB (CD10, CD11, CD12, CD30, CD31)	L.F.	5,250	$28.00	$147,000.00	$30.00	$157,500.00	$32.00	$168,000.00
18 CLASS "B" CONCRETE, MISCELLANEOUS	C.Y.	57	$580.00	$33,060.00	$480.00	$27,360.00	$270.00	$15,390.00
19 CLASS "B" CONCRETE, PLANTER AND BUILDING SLABS	C.Y.	24	$500.00	$12,000.00	$450.00	$10,800.00	$415.00	$9,960.00
20 INSTALL DECORATIVE CONCRETE FLATWORK	L.S.	1	$5,000.00	$5,000.00	$2,700.00	$2,700.00	$3,500.00	$3,500.00

Project Name: **L.I.D. Testing & Demonstration Facility, Parking Lot Renovation 2010, and Water Efficient Landscape Conversion**

Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

			RIVERSIDE CONSTRUCTION		STRONGHOLD ENGINEERING, INC.		4-CON ENGINEERING, INC.	
Item No. & Description	*Unit*	*Quantity*	*Unit Bid*	*Total Bid*	*Unit Bid*	*Total Bid*	*Unit Bid*	*Total Bid*
21 REINFORCED CONCRETE PIPE	L.F.	200	$85.00	$17,000.00	$85.00	$17,000.00	$125.00	$25,000.00
22 3" CLASS 2 AGGREGATE BASE DRIVEWAY AND ACCESS RAMP	C.Y.	10	$220.00	$2,200.00	$120.00	$1,200.00	$75.00	$750.00
23 PERVIOUS PAVERS OVER 2" #8 OVER 3" #57 OVER 13" #2 STONE	S.F.	25,400	$7.50	$190,500.00	$8.70	$220,980.00	$8.00	$203,200.00
24 PERVIOUS PAVERS OVER 2" #8 OVER 10-7/8" #57 STONE	S.F.	9,270	$6.50	$60,255.00	$7.00	$64,890.00	$7.00	$64,890.00
25 PERVIOUS PAVERS OVER 2" #8 OVER 3" #57 OVER 17" #2 STONE	S.F.	5,660	$8.50	$48,110.00	$10.00	$56,600.00	$9.00	$50,940.00
26 PERVIOUS PAVERS OVER 1" #8 OVER 4" #57 STONE	S.F.	1,184	$6.00	$7,104.00	$7.50	$8,880.00	$6.50	$7,696.00
27 8.5" PERVIOUS CONCRETE OVER 25" #57 STONE OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	2,360	$14.00	$33,040.00	$19.00	$44,840.00	$15.00	$35,400.00
28 8.5" PERVIOUS CONCRETE OVER 25" #57 STONE SURROUNDING 9" CLASS 2 AGGREGATE BASE AND FILTER FABRIC OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	2,090	$18.00	$37,620.00	$23.50	$49,115.00	$19.00	$39,710.00
29 5" POROUS ASPHALT OVER 25" #57 STONE OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	2,270	$13.00	$29,510.00	$10.00	$22,700.00	$13.00	$29,510.00
30 5" POROUS ASPHALT OVER 25" #57 STONE SURROUNDING 9" CLASS 2 AGGREGATE BASE AND FILTER FABRIC OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	1,700	$20.00	$34,000.00	$14.40	$24,480.00	$17.00	$28,900.00
31 4" AC OVER 6" CLASS 2 AGGREGATE BASE AND 4" AC OVER 11" CLASS 2 AGGREGATE BASE	S.F.	76,655	$4.00	$306,620.00	$2.70	$206,968.50	$3.00	$229,965.00
32 VARIABLE DEPTH AC OVERLAY	TONS	31	$135.00	$4,185.00	$130.00	$4,030.00	$90.00	$2,790.00
33 GRIND EXISTING AC PAVEMENT	S.F.	720	$4.00	$2,880.00	$5.60	$4,032.00	$6.00	$4,320.00
34 SLURRY SEAL	S.F.	35,800	$0.30	$10,740.00	$0.50	$17,900.00	$0.50	$17,900.00
35 BOLLARD	EACH	260	$150.00	$39,000.00	$172.00	$44,720.00	$175.00	$45,500.00

Project Name: **L.I.D. Testing & Demonstration Facility, Parking Lot Renovation 2010, and Water Efficient Landscape Conversion**

Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

			RIVERSIDE CONSTRUCTION		STRONGHOLD ENGINEERING, INC.		4-CON ENGINEERING, INC.	
Item No. & Description	*Unit*	*Quantity*	*Unit Bid*	*Total Bid*	*Unit Bid*	*Total Bid*	*Unit Bid*	*Total Bid*
36 4" PVC PIPE	L.F.	78	$12.00	$936.00	$11.00	$858.00	$12.00	$936.00
37 6" PVC PIPE	L.F.	2,126	$20.00	$42,520.00	$11.00	$23,386.00	$15.00	$31,890.00
38 8" PVC PIPE	L.F.	369	$30.00	$11,070.00	$30.00	$11,070.00	$25.00	$9,225.00
39 12" PVC PIPE	L.F.	314	$50.00	$15,700.00	$50.00	$15,700.00	$50.00	$15,700.00
40 18" PVC PIPE	L.F.	33	$95.00	$3,135.00	$70.00	$2,310.00	$75.00	$2,475.00
41 10" WIDE SLOTTED DRAIN	L.F.	177	$150.00	$26,550.00	$225.00	$39,825.00	$130.00	$23,010.00
42 PRECAST CONCRETE FLOW DETECTION CATCH BASIN	EACH	3	$850.00	$2,550.00	$700.00	$2,100.00	$400.00	$1,200.00
43 9"X9" PLASTIC CATCH BASIN	EACH	7	$475.00	$3,325.00	$200.00	$1,400.00	$250.00	$1,750.00
44 18"X18" PRECAST CONCRETE CATCH BASIN	EACH	2	$1,350.00	$2,700.00	$1,800.00	$3,600.00	$1,500.00	$3,000.00
45 24"X24" PRECAST CONCRETE CATCH BASIN	EACH	1	$1,500.00	$1,500.00	$1,700.00	$1,700.00	$2,000.00	$2,000.00
46 36"X36" PRECAST CONCRETE CATCH BASIN	EACH	5	$2,500.00	$12,500.00	$2,200.00	$11,000.00	$3,000.00	$15,000.00
47 GALVANIZED STEEL CATCH BASIN LID	EACH	1	$350.00	$350.00	$1,000.00	$1,000.00	$600.00	$600.00
48 PVC PIPE STORMWATER CLEANOUT	EACH	23	$850.00	$19,550.00	$300.00	$6,900.00	$325.00	$7,475.00
49 PRECAST CONCRETE HEADWALL FOR 8" PIPE	EACH	1	$500.00	$500.00	$1,200.00	$1,200.00	$2,800.00	$2,800.00
50 3" ELECTRICAL CONDUIT FROM PREFABRICATED BUILDING TO SAMPLING BASIN STRUCTURE	L.F.	530	$15.00	$7,950.00	$15.00	$7,950.00	$12.00	$6,360.00
51 NEW WHEEL STOPS	EACH	95	$35.00	$3,325.00	$40.00	$3,800.00	$30.00	$2,850.00
52 SIGNS INCLUDING POST AND FOOTING	EACH	2	$750.00	$1,500.00	$300.00	$600.00	$175.00	$350.00
53 PREFABRICATED 12'X22' BUILDING AND 2" ELECTRICAL CONDUIT FROM PULL BOX TO PREFABRICATED BUILDING	L.S.	1	$10,000.00	$10,000.00	$19,000.00	$19,000.00	$15,000.00	$15,000.00
54 3.5' HIGH METAL RAILING	L.F.	55	$100.00	$5,500.00	$185.00	$10,175.00	$180.00	$9,900.00
55 CONNECTION TO EXISTING BUILDING ROOF DOWNDRAINS	EACH	3	$850.00	$2,550.00	$520.00	$1,560.00	$350.00	$1,050.00
56 ENHANCED GRASS SWALE	L.S.	1	$10,000.00	$10,000.00	$4,700.00	$4,700.00	$20,000.00	$20,000.00
57 ADJUST MANHOLE AND VAULT TO GRADE	EACH	9	$550.00	$4,950.00	$1,050.00	$9,450.00	$550.00	$4,950.00

Item No. & Description	Unit	Quantity	RIVERSIDE CONSTRUCTION Unit Bid	RIVERSIDE CONSTRUCTION Total Bid	STRONGHOLD ENGINEERING, INC. Unit Bid	STRONGHOLD ENGINEERING, INC. Total Bid	4-CON ENGINEERING, INC. Unit Bid	4-CON ENGINEERING, INC. Total Bid
58 ADJUST VALVE AND CLEANOUT TO GRADE	EACH	13	$150.00	$1,950.00	$260.00	$3,380.00	$150.00	$1,950.00
59 COBBLE FILLED TRENCH	L.F.	430	$20.00	$8,600.00	$16.00	$6,880.00	$10.00	$4,300.00
60 4'X4' #2 STONE INFILTRATION TRENCH IN LAKE SMITHHAMMER	L.F.	220	$55.00	$12,100.00	$42.00	$9,240.00	$50.00	$11,000.00
61 #57 STONE IN LANDSCAPE FILTER BASIN AND FLOW THROUGH PLANTERS	C.Y.	31	$85.00	$2,635.00	$70.00	$2,170.00	$85.00	$2,635.00
62 MIRAFI FW402 FILTER FABRIC	S.F.	7,570	$0.25	$1,892.50	$0.70	$5,299.00	$1.00	$7,570.00
63 MIRAFI NT100 IMPERMEABLE BARRIER	S.F.	13,330	$0.65	$8,664.50	$1.50	$19,995.00	$1.50	$19,995.00
64 #2 STONE ENERGY DISSIPATERS	C.Y.	1	$500.00	$500.00	$120.00	$120.00	$500.00	$500.00
65 DUST ABATEMENT	L.S.	1	$15,000.00	$15,000.00	$9,500.00	$9,500.00	$10,000.00	$10,000.00
66 STORMWATER AND NON-STORMWATER POLLUTION CONTROL	L.S.	1	$25,000.00	$25,000.00	$14,700.00	$14,700.00	$12,000.00	$12,000.00
67 NON-STORMWATER DISCHARGE OR DEWATERING	L.S.	1	$1.00	$1.00	$6,000.00	$6,000.00	$1,000.00	$1,000.00
68 REMOVAL AND REPLACEMENT OF EXISTING UTILITIES AT NEW LANDSCAPE FILTER BASIN	L.F.	360	$30.00	$10,800.00	$16.00	$5,760.00	$50.00	$18,000.00
69 REMOVAL AND RELOCATION OF EXISTING IRRIGATION DOUBLE CHECK VALVE AND REMOVAL AND REPLACEMENT OF EXISTING 4-INCH WATERLINE	L.S.	1	$8,500.00	$8,500.00	$3,800.00	$3,800.00	$12,000.00	$12,000.00
70 FILTRATION SOIL MIXTURE	C.Y.	90	$85.00	$7,650.00	$64.00	$5,760.00	$75.00	$6,750.00
71 IRRIGATION SYSTEM	L.S.	1	$275,000.00	$275,000.00	$271,000.00	$271,000.00	$275,000.00	$275,000.00
72 SOIL TESTING AND SOIL PREPARATION	S.F.	182,100	$0.20	$36,420.00	$0.14	$25,494.00	$0.15	$27,315.00
73 MOW CURBING	L.F.	2,875	$8.00	$23,000.00	$4.50	$12,937.50	$9.00	$25,875.00
74 WOOD CHIPS	S.F.	145,600	$0.20	$29,120.00	$0.44	$64,064.00	$0.25	$36,400.00
75 DECOMPOSED GRANITE	S.F.	2,080	$7.00	$14,560.00	$1.30	$2,704.00	$1.50	$3,120.00
76 CRUSHED ROCK	S.F.	2,100	$7.00	$14,700.00	$2.00	$4,200.00	$1.75	$3,675.00
77 DRIVABLE GRASS	S.F.	785	$10.00	$7,850.00	$5.60	$4,396.00	$6.50	$5,102.50
78 SYNTHETIC TURF	S.F.	315	$10.00	$3,150.00	$14.00	$4,410.00	$13.00	$4,095.00
79 SOD	S.F.	36,500	$0.50	$18,250.00	$0.60	$21,900.00	$0.70	$25,550.00

Project Name: **L.I.D. Testing & Demonstration Facility, Parking Lot Renovation 2010, and Water Efficient Landscape Conversion**

Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

					RIVERSIDE CONSTRUCTION		STRONGHOLD ENGINEERING, INC.		4-CON ENGINEERING, INC.	
Item	***No. & Description***	***Unit***	***Quantity***		***Unit Bid***	***Total Bid***	***Unit Bid***	***Total Bid***	***Unit Bid***	***Total Bid***
80	FLATS	EACH	675		$16.00	$10,800.00	$18.00	$12,150.00	$28.00	$18,900.00
81	1-GALLON	EACH	2,800		$6.00	$16,800.00	$5.40	$15,120.00	$6.00	$16,800.00
82	2-GALLON	EACH	98		$15.00	$1,470.00	$19.00	$1,862.00	$10.00	$980.00
83	5-GALLON	EACH	1,575		$13.00	$20,475.00	$15.00	$23,625.00	$16.00	$25,200.00
84	15-GALLON	EACH	18		$73.00	$1,314.00	$75.00	$1,350.00	$100.00	$1,800.00
85	15-GALLON CITRUS	EACH	62		$125.00	$7,750.00	$100.00	$6,200.00	$140.00	$8,680.00
86	24" BOX	EACH	138		$185.00	$25,530.00	$150.00	$20,700.00	$200.00	$27,600.00
87	36" BOX	EACH	7		$425.00	$2,975.00	$550.00	$3,850.00	$550.00	$3,850.00
88	48" BOX	EACH	1		$995.00	$995.00	$1,500.00	$1,500.00	$1,500.00	$1,500.00
89	6' BROWN TRUNK PALM	EACH	2		$910.00	$1,820.00	$1,100.00	$2,200.00	$1,200.00	$2,400.00
90	TREE GRATE	EACH	2		$1,250.00	$2,500.00	$1,300.00	$2,600.00	$1,500.00	$3,000.00
91	PICNIC TABLE	EACH	5		$1,600.00	$8,000.00	$1,300.00	$6,500.00	$1,400.00	$7,000.00
92	WASTE CONTAINER	EACH	9		$850.00	$7,650.00	$660.00	$5,940.00	$725.00	$6,525.00
93	FOUNTAIN	EACH	1		$3,800.00	$3,800.00	$860.00	$860.00	$2,200.00	$2,200.00
94	FLAG POLE	EACH	2		$5,700.00	$11,400.00	$2,060.00	$4,120.00	$5,200.00	$10,400.00
95	CONCRETE POT #13	EACH	4		$950.00	$3,800.00	$870.00	$3,480.00	$1,100.00	$4,400.00
96	CONCRETE POT #13A	EACH	8		$1,000.00	$8,000.00	$920.00	$7,360.00	$950.00	$7,600.00
97	CONCRETE POT #13B	EACH	4		$500.00	$2,000.00	$400.00	$1,600.00	$600.00	$2,400.00
98	CONCRETE BENCH #10	EACH	8		$600.00	$4,800.00	$500.00	$4,000.00	$650.00	$5,200.00
99	CONCRETE BENCH #15	EACH	6		$600.00	$3,600.00	$500.00	$3,000.00	$650.00	$3,900.00
100	LANDSCAPE MAINTENANCE	L.S.	1		$6,500.00	$6,500.00	$6,000.00	$6,000.00	$6,000.00	$6,000.00
101	ELECTRICAL LIGHTING FIXTURE A	EACH	24		$1,150.00	$27,600.00	$1,200.00	$28,800.00	$1,400.00	$33,600.00
102	ELECTRICAL LIGHTING FIXTURE B	EACH	2		$1,150.00	$2,300.00	$1,500.00	$3,000.00	$1,400.00	$2,800.00
103	ELECTRICAL LIGHTING FIXTURE C	EACH	5		$2,600.00	$13,000.00	$3,500.00	$17,500.00	$2,500.00	$12,500.00
104	ELECTRICAL LIGHTING FIXTURE D	EACH	9		$2,800.00	$25,200.00	$3,500.00	$31,500.00	$4,200.00	$37,800.00
105	ELECTRICAL LIGHTING FIXTURE E	EACH	4		$1,100.00	$4,400.00	$1,000.00	$4,000.00	$1,200.00	$4,800.00
106	ELECTRICAL CONDUIT AND WIRE	L.F.	4,450		$12.00	$53,400.00	$14.00	$62,300.00	$16.00	$71,200.00
						$2,968,200.00		**$3,102,563.00**		**$3,145,844.50**

Project Name: **L.I.D. Testing & Demonstration Facility, Parking Lot Renovation 2010, and Water Efficient Landscape Conversion**

Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

Item	No. & Description	Unit	Quantity	COOLEY CONSTRUCTION, INC. Unit Bid	COOLEY CONSTRUCTION, INC. Total Bid	MALLCRAFT, INC. Unit Bid	MALLCRAFT, INC. Total Bid	SIALIC CONTRACTORS CORPORATED dba SHAWNAN Unit Bid	SIALIC CONTRACTORS CORPORATED dba SHAWNAN Total Bid
1	MOBILIZATION	L.S.	1	$296,126.00	$296,126.00	$100,000.00	$100,000.00	$220,000.00	$220,000.00
2	WATER CONTROL	L.S.	1	$30,000.00	$30,000.00	$100,000.00	$100,000.00	$20,000.00	$20,000.00
3	TRAFFIC CONTROL	L.S.	1	$45,000.00	$45,000.00	$5,750.00	$5,750.00	$15,000.00	$15,000.00
4	CLEARING AND MISCELLANEOUS WORK	L.S.	1	$226,000.00	$226,000.00	$200,000.00	$200,000.00	;1,838,000.00	$1,838,000.00
5	EXTRA DIRECTED WORK	L.S.	1	$150,000.00	$150,000.00	$150,000.00	$150,000.00	$150,000.00	$150,000.00
6	EXCAVATION	C.Y.	7,230	$27.30	$197,379.00	$17.25	$124,717.50	$10.00	$72,300.00
7	TRENCH SAFETY SYSTEM	L.S.	1	$1,670.00	$1,670.00	$1,150.00	$1,150.00	$5,000.00	$5,000.00
8	CLASS "A" CONCRETE, 3'X3' CLEANOUT STRUCTURE AND SAMPLING VAULT	EACH	9	$3,200.00	$28,800.00	$1,610.00	$14,490.00	$300.00	$2,700.00
9	CLASS "A" CONCRETE, TRANSITION STRUCTURE NO. 3	EACH	3	$2,430.00	$7,290.00	$1,800.00	$5,400.00	$750.00	$2,250.00
10	CLASS "A" CONCRETE, UNDER SIDEWALK DRAIN	EACH	3	$2,770.00	$8,310.00	$2,760.00	$8,280.00	$1,000.00	$3,000.00
11	CLASS "A" CONCRETE, FOOTING AND CMU RAISED PLANTERS AND ENTRY SIGN WALLS	L.F.	158	$250.00	$39,500.00	$109.25	$17,261.50	$100.00	$15,800.00
12	CLASS "A" CONCRETE, CMU FLOW THROUGH PLANTER WALLS	L.F.	183	$250.00	$45,750.00	$109.25	$19,992.75	$95.00	$17,385.00
13	CLASS "A" CONCRETE, LANDSCAPE FILTER BASIN RETAINING WALL	C.Y.	48	$620.00	$29,760.00	$460.00	$22,080.00	$300.00	$14,400.00
14	CLASS "A" CONCRETE, SAMPLING BASIN STRUCTURE	EACH	1	$21,000.00	$21,000.00	$10,000.00	$10,000.00	$1,800.00	$1,800.00
15	CLASS "B" CONCRETE, CURB AND GUTTER (CD1, CD2, CD3, CD9)	L.F.	984	$14.50	$14,268.00	$22.08	$21,726.72	$9.00	$8,856.00
16	CLASS "B" CONCRETE, STANDARD CURB (CD4, CD5, CD6, CD7, CD8, CD24, CD26)	L.F.	3,500	$10.00	$35,000.00	$17.74	$62,090.00	$5.00	$17,500.00
17	CLASS "B" CONCRETE, DEEPENED CURB (CD10, CD11, CD12, CD30, CD31)	L.F.	5,250	$10.70	$56,175.00	$52.11	$273,577.50	$6.00	$31,500.00
18	CLASS "B" CONCRETE, MISCELLANEOUS	C.Y.	57	$670.00	$38,190.00	$1,113.42	$63,464.94	$350.00	$19,950.00
19	CLASS "B" CONCRETE, PLANTER AND BUILDING SLABS	C.Y.	24	$830.00	$19,920.00	$460.00	$11,040.00	$400.00	$9,600.00
20	INSTALL DECORATIVE CONCRETE FLATWORK	L.S.	1	$10,800.00	$10,800.00	$40,000.00	$40,000.00	$4,500.00	$4,500.00

Project Name: **L.I.D. Testing & Demonstration Facility, Parking Lot Renovation 2010, and Water Efficient Landscape Conversion**

Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

			COOLEY CONSTRUCTION, INC.		MALLCRAFT, INC.		SIALIC CONTRACTORS CORPORATED dba SHAWNAN	
Item No. & Description	*Unit*	*Quantity*	*Unit Bid*	*Total Bid*	*Unit Bid*	*Total Bid*	*Unit Bid*	*Total Bid*
21 REINFORCED CONCRETE PIPE	L.F.	200	$130.00	$26,000.00	$92.00	$18,400.00	$75.00	$15,000.00
22 3" CLASS 2 AGGREGATE BASE DRIVEWAY AND ACCESS RAMP	C.Y.	10	$178.00	$1,780.00	$143.75	$1,437.50	$200.00	$2,000.00
23 PERVIOUS PAVERS OVER 2" #8 OVER 3" #57 OVER 13" #2 STONE	S.F.	25,400	$7.90	$200,660.00	$10.98	$278,892.00	$5.00	$127,000.00
24 PERVIOUS PAVERS OVER 2" #8 OVER 10-7/8" #57 STONE	S.F.	9,270	$7.00	$64,890.00	$10.98	$101,784.60	$5.50	$50,985.00
25 PERVIOUS PAVERS OVER 2" #8 OVER 3" #57 OVER 17" #2 STONE	S.F.	5,660	$9.60	$54,336.00	$10.98	$62,146.80	$5.75	$32,545.00
26 PERVIOUS PAVERS OVER 1" #8 OVER 4" #57 STONE	S.F.	1,184	$7.50	$8,880.00	$10.98	$13,000.32	$4.00	$4,736.00
27 8.5" PERVIOUS CONCRETE OVER 25" #57 STONE OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	2,360	$12.70	$29,972.00	$13.80	$32,568.00	$5.00	$11,800.00
28 8.5" PERVIOUS CONCRETE OVER 25" #57 STONE SURROUNDING 9" CLASS 2 AGGREGATE BASE AND FILTER FABRIC OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	2,090	$13.70	$28,633.00	$14.95	$31,245.50	$6.00	$12,540.00
29 5" POROUS ASPHALT OVER 25" #57 STONE OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	2,270	$7.50	$17,025.00	$13.80	$31,326.00	$4.00	$9,080.00
30 5" POROUS ASPHALT OVER 25" #57 STONE SURROUNDING 9" CLASS 2 AGGREGATE BASE AND FILTER FABRIC OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	1,700	$9.30	$15,810.00	$15.00	$25,500.00	$4.25	$7,225.00
31 4" AC OVER 6" CLASS 2 AGGREGATE BASE AND 4" AC OVER 11" CLASS 2 AGGREGATE BASE	S.F.	76,655	$3.45	$264,459.75	$3.68	$282,090.40	$1.25	$95,818.75
32 VARIABLE DEPTH AC OVERLAY	TONS	31	$96.00	$2,976.00	$78.20	$2,424.20	$180.00	$5,580.00
33 GRIND EXISTING AC PAVEMENT	S.F.	720	$3.80	$2,736.00	$6.04	$4,348.80	$3.00	$2,160.00
34 SLURRY SEAL	S.F.	35,800	$0.27	$9,666.00	$0.17	$6,086.00	$0.15	$5,370.00
35 BOLLARD	EACH	260	$220.00	$57,200.00	$149.50	$38,870.00	$75.00	$19,500.00

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Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

			COOLEY CONSTRUCTION, INC.		MALLCRAFT, INC.		SIALIC CONTRACTORS CORPORATED dba SHAWNAN	
Item No. & Description	*Unit*	*Quantity*	*Unit Bid*	*Total Bid*	*Unit Bid*	*Total Bid*	*Unit Bid*	*Total Bid*
36 4" PVC PIPE	L.F.	78	$24.00	$1,872.00	$40.00	$3,120.00	$25.00	$1,950.00
37 6" PVC PIPE	L.F.	2,126	$24.00	$51,024.00	$46.00	$97,796.00	$12.00	$25,512.00
38 8" PVC PIPE	L.F.	369	$26.60	$9,815.40	$63.25	$23,339.25	$15.00	$5,535.00
39 12" PVC PIPE	L.F.	314	$38.00	$11,932.00	$138.00	$43,332.00	$25.00	$7,850.00
40 18" PVC PIPE	L.F.	33	$63.00	$2,079.00	$172.50	$5,692.50	$35.00	$1,155.00
41 10" WIDE SLOTTED DRAIN	L.F.	177	$220.00	$38,940.00	$207.00	$36,639.00	$25.00	$4,425.00
42 PRECAST CONCRETE FLOW DETECTION CATCH BASIN	EACH	3	$1,270.00	$3,810.00	$1,090.00	$3,270.00	$800.00	$2,400.00
43 9"X9" PLASTIC CATCH BASIN	EACH	7	$160.00	$1,120.00	$230.00	$1,610.00	$200.00	$1,400.00
44 18"X18" PRECAST CONCRETE CATCH BASIN	EACH	2	$2,700.00	$5,400.00	$805.00	$1,610.00	$750.00	$1,500.00
45 24"X24" PRECAST CONCRETE CATCH BASIN	EACH	1	$2,900.00	$2,900.00	$1,090.00	$1,090.00	$1,000.00	$1,000.00
46 36"X36" PRECAST CONCRETE CATCH BASIN	EACH	5	$3,430.00	$17,150.00	$1,500.00	$7,500.00	$1,200.00	$6,000.00
47 GALVANIZED STEEL CATCH BASIN LID	EACH	1	$580.00	$580.00	$977.50	$977.50	$300.00	$300.00
48 PVC PIPE STORMWATER CLEANOUT	EACH	23	$390.00	$8,970.00	$575.00	$13,225.00	$200.00	$4,600.00
49 PRECAST CONCRETE HEADWALL FOR 8" PIPE	EACH	1	$1,490.00	$1,490.00	$4,830.00	$4,830.00	$500.00	$500.00
50 3" ELECTRICAL CONDUIT FROM PREFABRICATED BUILDING TO SAMPLING BASIN STRUCTURE	L.F.	530	$10.00	$5,300.00	$15.24	$8,077.20	$10.00	$5,300.00
51 NEW WHEEL STOPS	EACH	95	$66.00	$6,270.00	$120.75	$11,471.25	$40.00	$3,800.00
52 SIGNS INCLUDING POST AND FOOTING	EACH	2	$248.00	$496.00	$402.50	$805.00	$200.00	$400.00
53 PREFABRICATED 12'X22' BUILDING AND 2" ELECTRICAL CONDUIT FROM PULL BOX TO PREFABRICATED BUILDING	L.S.	1	$15,000.00	$15,000.00	$14,620.00	$14,620.00	$9,500.00	$9,500.00
54 3.5' HIGH METAL RAILING	L.F.	55	$330.00	$18,150.00	$184.00	$10,120.00	$75.00	$4,125.00
55 CONNECTION TO EXISTING BUILDING ROOF DOWNDRAINS	EACH	3	$1,330.00	$3,990.00	$74.75	$224.25	$30.00	$90.00
56 ENHANCED GRASS SWALE	L.S.	1	$10,900.00	$10,900.00	$100,000.00	$100,000.00	$3,000.00	$3,000.00
57 ADJUST MANHOLE AND VAULT TO GRADE	EACH	9	$1,330.00	$11,970.00	$747.50	$6,727.50	$300.00	$2,700.00

Project Name: **L.I.D. Testing & Demonstration Facility, Parking Lot Renovation 2010, and Water Efficient Landscape Conversion**

Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

Item No. & Description	Unit	Quantity	COOLEY CONSTRUCTION, INC. Unit Bid	COOLEY CONSTRUCTION, INC. Total Bid	MALLCRAFT, INC. Unit Bid	MALLCRAFT, INC. Total Bid	SIALIC CONTRACTORS CORPORATED dba SHAWNAN Unit Bid	SIALIC CONTRACTORS CORPORATED dba SHAWNAN Total Bid
58 ADJUST VALVE AND CLEANOUT TO GRADE	EACH	13	$220.00	$2,860.00	$517.50	$6,727.50	$325.00	$4,225.00
59 COBBLE FILLED TRENCH	L.F.	430	$18.40	$7,912.00	$10.35	$4,450.50	$10.00	$4,300.00
60 4'X4' #2 STONE INFILTRATION TRENCH IN LAKE SMITHHAMMER	L.F.	220	$78.00	$17,160.00	$80.50	$17,710.00	$50.00	$11,000.00
61 #57 STONE IN LANDSCAPE FILTER BASIN AND FLOW THROUGH PLANTERS	C.Y.	31	$220.00	$6,820.00	$101.20	$3,137.20	$75.00	$2,325.00
62 MIRAFI FW402 FILTER FABRIC	S.F.	7,570	$0.90	$6,813.00	$0.38	$2,876.60	$0.10	$757.00
63 MIRAFI NT100 IMPERMEABLE BARRIER	S.F.	13,330	$1.53	$20,394.90	$1.35	$17,995.50	$0.12	$1,599.60
64 #2 STONE ENERGY DISSIPATERS	C.Y.	1	$290.00	$290.00	$115.00	$115.00	$200.00	$200.00
65 DUST ABATEMENT	L.S.	1	$17,200.00	$17,200.00	$11,500.00	$11,500.00	$20,000.00	$20,000.00
66 STORMWATER AND NON-STORMWATER POLLUTION CONTROL	L.S.	1	$55,000.00	$55,000.00	$23,000.00	$23,000.00	$20,000.00	$20,000.00
67 NON-STORMWATER DISCHARGE OR DEWATERING	L.S.	1	$25,000.00	$25,000.00	$5,750.00	$5,750.00	$10,000.00	$10,000.00
68 REMOVAL AND REPLACEMENT OF EXISTING UTILITIES AT NEW LANDSCAPE FILTER BASIN	L.F.	360	$27.70	$9,972.00	$34.50	$12,420.00	$10.00	$3,600.00
69 REMOVAL AND RELOCATION OF EXISTING IRRIGATION DOUBLE CHECK VALVE AND REMOVAL AND REPLACEMENT OF EXISTING 4-INCH WATERLINE	L.S.	1	$5,300.00	$5,300.00	$5,180.00	$5,180.00	$5,000.00	$5,000.00
70 FILTRATION SOIL MIXTURE	C.Y.	90	$42.00	$3,780.00	$65.55	$5,899.50	$40.00	$3,600.00
71 IRRIGATION SYSTEM	L.S.	1	$274,000.00	$274,000.00	$241,500.00	$241,500.00	$225,000.00	$225,000.00
72 SOIL TESTING AND SOIL PREPARATION	S.F.	182,100	$0.15	$27,315.00	$0.29	$52,809.00	$0.15	$27,315.00
73 MOW CURBING	L.F.	2,875	$12.80	$36,800.00	$6.28	$18,055.00	$9.00	$25,875.00
74 WOOD CHIPS	S.F.	145,600	$0.32	$46,592.00	$0.38	$55,328.00	$0.10	$14,560.00
75 DECOMPOSED GRANITE	S.F.	2,080	$0.87	$1,809.60	$1.76	$3,660.80	$0.50	$1,040.00
76 CRUSHED ROCK	S.F.	2,100	$1.80	$3,780.00	$2.48	$5,208.00	$1.00	$2,100.00
77 DRIVABLE GRASS	S.F.	785	$2.14	$1,679.90	$9.04	$7,096.40	$5.00	$3,925.00
78 SYNTHETIC TURF	S.F.	315	$17.00	$5,355.00	$32.32	$10,180.80	$19.00	$5,985.00
79 SOD	S.F.	36,500	$0.62	$22,630.00	$0.58	$21,170.00	$0.35	$12,775.00

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Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

			COOLEY CONSTRUCTION, INC.		MALLCRAFT, INC.		SIALIC CONTRACTORS CORPORATED dba SHAWNAN	
Item No. & Description	*Unit*	*Quantity*	*Unit Bid*	*Total Bid*	*Unit Bid*	*Total Bid*	*Unit Bid*	*Total Bid*
80 FLATS	EACH	675	$13.80	$9,315.00	$24.09	$16,260.75	$10.00	$6,750.00
81 1-GALLON	EACH	2,800	$8.90	$24,920.00	$7.11	$19,908.00	$4.00	$11,200.00
82 2-GALLON	EACH	98	$13.20	$1,293.60	$15.90	$1,558.20	$10.00	$980.00
83 5-GALLON	EACH	1,575	$14.40	$22,680.00	$19.34	$30,460.50	$9.00	$14,175.00
84 15-GALLON	EACH	18	$77.00	$1,386.00	$106.34	$1,914.12	$60.00	$1,080.00
85 15-GALLON CITRUS	EACH	62	$140.00	$8,680.00	$183.89	$11,401.18	$100.00	$6,200.00
86 24" BOX	EACH	138	$220.00	$30,360.00	$264.29	$36,472.02	$150.00	$20,700.00
87 36" BOX	EACH	7	$390.00	$2,730.00	$588.81	$4,121.67	$375.00	$2,625.00
88 48" BOX	EACH	1	$870.00	$870.00	$1,280.00	$1,280.00	$700.00	$700.00
89 6' BROWN TRUNK PALM	EACH	2	$156.00	$312.00	$894.93	$1,789.86	$800.00	$1,600.00
90 TREE GRATE	EACH	2	$1,010.00	$2,020.00	$1,440.00	$2,880.00	$700.00	$1,400.00
91 PICNIC TABLE	EACH	5	$1,770.00	$8,850.00	$1,420.00	$7,100.00	$700.00	$3,500.00
92 WASTE CONTAINER	EACH	9	$980.00	$8,820.00	$776.25	$6,986.25	$500.00	$4,500.00
93 FOUNTAIN	EACH	1	$570.00	$570.00	$2,070.00	$2,070.00	$1,000.00	$1,000.00
94 FLAG POLE	EACH	2	$2,570.00	$5,140.00	$5,150.00	$10,300.00	$1,200.00	$2,400.00
95 CONCRETE POT #13	EACH	4	$1,000.00	$4,000.00	$977.50	$3,910.00	$900.00	$3,600.00
96 CONCRETE POT #13A	EACH	8	$1,000.00	$8,000.00	$1,020.00	$8,160.00	$900.00	$7,200.00
97 CONCRETE POT #13B	EACH	4	$780.00	$3,120.00	$488.75	$1,955.00	$400.00	$1,600.00
98 CONCRETE BENCH #10	EACH	8	$890.00	$7,120.00	$626.75	$5,014.00	$500.00	$4,000.00
99 CONCRETE BENCH #15	EACH	6	$890.00	$5,340.00	$626.75	$3,760.50	$375.00	$2,250.00
100 LANDSCAPE MAINTENANCE	L.S.	1	$10,000.00	$10,000.00	$5,270.00	$5,270.00	$4,000.00	$4,000.00
101 ELECTRICAL LIGHTING FIXTURE A	EACH	24	$1,220.00	$29,280.00	$1,397.25	$33,534.00	$900.00	$21,600.00
102 ELECTRICAL LIGHTING FIXTURE B	EACH	2	$1,330.00	$2,660.00	$1,440.00	$2,880.00	$800.00	$1,600.00
103 ELECTRICAL LIGHTING FIXTURE C	EACH	5	$2,330.00	$11,650.00	$3,000.00	$15,000.00	$2,000.00	$10,000.00
104 ELECTRICAL LIGHTING FIXTURE D	EACH	9	$3,900.00	$35,100.00	$4,030.00	$36,270.00	$3,000.00	$27,000.00
105 ELECTRICAL LIGHTING FIXTURE E	EACH	4	$1,100.00	$4,400.00	$994.75	$3,979.00	$400.00	$1,600.00
106 ELECTRICAL CONDUIT AND WIRE	L.F.	4,450	$19.40	$86,330.00	$21.56	$95,942.00	$13.00	$57,850.00
				$3,248,530.15		**$3,479,164.33**		**$3,590,214.35**

Project Name: **L.I.D. Testing & Demonstration Facility, Parking Lot Renovation 2010, and Water Efficient Landscape Conversion**

Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

Item	No. & Description	Unit	Quantity	MINAKO AMERICA CORPORATION dba MINCO CONSTRUCTION Unit Bid	Total Bid
1	MOBILIZATION	L.S.	1	$100,000.00	$100,000.00
2	WATER CONTROL	L.S.	1	$25,000.00	$25,000.00
3	TRAFFIC CONTROL	L.S.	1	$25,000.00	$25,000.00
4	CLEARING AND MISCELLANEOUS WORK	L.S.	1	$100,000.00	$100,000.00
5	EXTRA DIRECTED WORK	L.S.	1	$150,000.00	$150,000.00
6	EXCAVATION	C.Y.	7,230	$25.00	$180,750.00
7	TRENCH SAFETY SYSTEM	L.S.	1	$50,000.00	$50,000.00
8	CLASS "A" CONCRETE, 3'X3' CLEANOUT STRUCTURE AND SAMPLING VAULT	EACH	9	$5,000.00	$45,000.00
9	CLASS "A" CONCRETE, TRANSITION STRUCTURE NO. 3	EACH	3	$5,000.00	$15,000.00
10	CLASS "A" CONCRETE, UNDER SIDEWALK DRAIN	EACH	3	$1,000.00	$3,000.00
11	CLASS "A" CONCRETE, FOOTING AND CMU RAISED PLANTERS AND ENTRY SIGN WALLS	L.F.	158	$100.00	$15,800.00
12	CLASS "A" CONCRETE, CMU FLOW THROUGH PLANTER WALLS	L.F.	183	$50.00	$9,150.00
13	CLASS "A" CONCRETE, LANDSCAPE FILTER BASIN RETAINING WALL	C.Y.	48	$1,000.00	$48,000.00
14	CLASS "A" CONCRETE, SAMPLING BASIN STRUCTURE	EACH	1	$25,000.00	$25,000.00
15	CLASS "B" CONCRETE, CURB AND GUTTER (CD1, CD2, CD3, CD9)	L.F.	984	$100.00	$98,400.00
16	CLASS "B" CONCRETE, STANDARD CURB (CD4, CD5, CD6, CD7, CD8, CD24, CD26)	L.F.	3,500	$25.00	$87,500.00
17	CLASS "B" CONCRETE, DEEPENED CURB (CD10, CD11, CD12, CD30, CD31)	L.F.	5,250	$50.00	$262,500.00
18	CLASS "B" CONCRETE, MISCELLANEOUS	C.Y.	57	$500.00	$28,500.00
19	CLASS "B" CONCRETE, PLANTER AND BUILDING SLABS	C.Y.	24	$1,000.00	$24,000.00
20	INSTALL DECORATIVE CONCRETE FLATWORK	L.S.	1	$10,000.00	$10,000.00

Project Name: **L.I.D. Testing & Demonstration Facility, Parking Lot Renovation 2010, and Water Efficient Landscape Conversion**

Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

Item	No. & Description	Unit	Quantity	MINAKO AMERICA CORPORATION dba MINCO CONSTRUCTION Unit Bid	Total Bid		
21	REINFORCED CONCRETE PIPE	L.F.	200	$75.00	$15,000.00		
22	3" CLASS 2 AGGREGATE BASE DRIVEWAY AND ACCESS RAMP	C.Y.	10	$100.00	$1,000.00		
23	PERVIOUS PAVERS OVER 2" #8 OVER 3" #57 OVER 13" #2 STONE	S.F.	25,400	$15.00	$381,000.00		
24	PERVIOUS PAVERS OVER 2" #8 OVER 10-7/8" #57 STONE	S.F.	9,270	$15.00	$139,050.00		
25	PERVIOUS PAVERS OVER 2" #8 OVER 3" #57 OVER 17" #2 STONE	S.F.	5,660	$20.00	$113,200.00		
26	PERVIOUS PAVERS OVER 1" #8 OVER 4" #57 STONE	S.F.	1,184	$15.00	$17,760.00		
27	8.5" PERVIOUS CONCRETE OVER 25" #57 STONE OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	2,360	$15.00	$35,400.00		
28	8.5" PERVIOUS CONCRETE OVER 25" #57 STONE SURROUNDING 9" CLASS 2 AGGREGATE BASE AND FILTER FABRIC OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	2,090	$15.00	$31,350.00		
29	5" POROUS ASPHALT OVER 25" #57 STONE OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	2,270	$15.00	$34,050.00		
30	5" POROUS ASPHALT OVER 25" #57 STONE SURROUNDING 9" CLASS 2 AGGREGATE BASE AND FILTER FABRIC OVER IMPERMEABLE COMPOSITE BARRIER	S.F.	1,700	$15.00	$25,500.00		
31	4" AC OVER 6" CLASS 2 AGGREGATE BASE AND 4" AC OVER 11" CLASS 2 AGGREGATE BASE	S.F.	76,655	$5.00	$383,275.00		
32	VARIABLE DEPTH AC OVERLAY	TONS	31	$100.00	$3,100.00		
33	GRIND EXISTING AC PAVEMENT	S.F.	720	$5.00	$3,600.00		
34	SLURRY SEAL	S.F.	35,800	$1.00	$35,800.00		
35	BOLLARD	EACH	260	$300.00	$78,000.00		

Project Name: **L.I.D. Testing & Demonstration Facility, Parking Lot Renovation 2010, and Water Efficient Landscape Conversion**

Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

Item	No. & Description	Unit	Quantity	MINAKO AMERICA CORPORATION dba MINCO CONSTRUCTION Unit Bid	Total Bid
36	4" PVC PIPE	L.F.	78	$100.00	$7,800.00
37	6" PVC PIPE	L.F.	2,126	$35.00	$74,410.00
38	8" PVC PIPE	L.F.	369	$50.00	$18,450.00
39	12" PVC PIPE	L.F.	314	$100.00	$31,400.00
40	18" PVC PIPE	L.F.	33	$200.00	$6,600.00
41	10" WIDE SLOTTED DRAIN	L.F.	177	$100.00	$17,700.00
42	PRECAST CONCRETE FLOW DETECTION CATCH BASIN	EACH	3	$5,000.00	$15,000.00
43	9"X9" PLASTIC CATCH BASIN	EACH	7	$200.00	$1,400.00
44	18"X18" PRECAST CONCRETE CATCH BASIN	EACH	2	$1,000.00	$2,000.00
45	24"X24" PRECAST CONCRETE CATCH BASIN	EACH	1	$3,000.00	$3,000.00
46	36"X36" PRECAST CONCRETE CATCH BASIN	EACH	5	$4,000.00	$20,000.00
47	GALVANIZED STEEL CATCH BASIN LID	EACH	1	$1,000.00	$1,000.00
48	PVC PIPE STORMWATER CLEANOUT	EACH	23	$500.00	$11,500.00
49	PRECAST CONCRETE HEADWALL FOR 8" PIPE	EACH	1	$5,000.00	$5,000.00
50	3" ELECTRICAL CONDUIT FROM PREFABRICATED BUILDING TO SAMPLING BASIN STRUCTURE	L.F.	530	$20.00	$10,600.00
51	NEW WHEEL STOPS	EACH	95	$100.00	$9,500.00
52	SIGNS INCLUDING POST AND FOOTING	EACH	2	$1,000.00	$2,000.00
53	PREFABRICATED 12'X22' BUILDING AND 2" ELECTRICAL CONDUIT FROM PULL BOX TO PREFABRICATED BUILDING	L.S.	1	$125,000.00	$125,000.00
54	3.5' HIGH METAL RAILING	L.F.	55	$100.00	$5,500.00
55	CONNECTION TO EXISTING BUILDING ROOF DOWNDRAINS	EACH	3	$1,000.00	$3,000.00
56	ENHANCED GRASS SWALE	L.S.	1	$3,750.00	$3,750.00
57	ADJUST MANHOLE AND VAULT TO GRADE	EACH	9	$1,000.00	$9,000.00

Project Name: **L.I.D. Testing & Demonstration Facility, Parking Lot Renovation 2010, and Water Efficient Landscape Conversion**

Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

Item	No. & Description	Unit	Quantity	MINAKO AMERICA CORPORATION dba MINCO CONSTRUCTION Unit Bid	Total Bid
58	ADJUST VALVE AND CLEANOUT TO GRADE	EACH	13	$500.00	$6,500.00
59	COBBLE FILLED TRENCH	L.F.	430	$10.00	$4,300.00
60	4'X4' #2 STONE INFILTRATION TRENCH IN LAKE SMITHHAMMER	L.F.	220	$150.00	$33,000.00
61	#57 STONE IN LANDSCAPE FILTER BASIN AND FLOW THROUGH PLANTERS	C.Y.	31	$100.00	$3,100.00
62	MIRAFI FW402 FILTER FABRIC	S.F.	7,570	$1.00	$7,570.00
63	MIRAFI NT100 IMPERMEABLE BARRIER	S.F.	13,330	$1.00	$13,330.00
64	#2 STONE ENERGY DISSIPATERS	C.Y.	1	$1,000.00	$1,000.00
65	DUST ABATEMENT	L.S.	1	$5,000.00	$5,000.00
66	STORMWATER AND NON-STORMWATER POLLUTION CONTROL	L.S.	1	$15,000.00	$15,000.00
67	NON-STORMWATER DISCHARGE OR DEWATERING	L.S.	1	$15,000.00	$15,000.00
68	REMOVAL AND REPLACEMENT OF EXISTING UTILITIES AT NEW LANDSCAPE FILTER BASIN	L.F.	360	$10.00	$3,600.00
69	REMOVAL AND RELOCATION OF EXISTING IRRIGATION DOUBLE CHECK VALVE AND REMOVAL AND REPLACEMENT OF EXISTING 4-INCH WATERLINE	L.S.	1	$10,000.00	$10,000.00
70	FILTRATION SOIL MIXTURE	C.Y.	90	$100.00	$9,000.00
71	IRRIGATION SYSTEM	L.S.	1	$250,000.00	$250,000.00
72	SOIL TESTING AND SOIL PREPARATION	S.F.	182,100	$0.22	$40,062.00
73	MOW CURBING	L.F.	2,875	$10.00	$28,750.00
74	WOOD CHIPS	S.F.	145,600	$0.20	$29,120.00
75	DECOMPOSED GRANITE	S.F.	2,080	$10.00	$20,800.00
76	CRUSHED ROCK	S.F.	2,100	$2.00	$4,200.00
77	DRIVABLE GRASS	S.F.	785	$10.00	$7,850.00
78	SYNTHETIC TURF	S.F.	315	$30.00	$9,450.00
79	SOD	S.F.	36,500	$0.50	$18,250.00

Project Name: **L.I.D. Testing & Demonstration Facility, Parking Lot Renovation 2010, and Water Efficient Landscape Conversion**

Project Number: 0-4-1027-00
Bid Open Date: 09/07/2010

Item No. & Description	Unit	Quantity	MINAKO AMERICA CORPORATION dba MINCO CONSTRUCTION Unit Bid	Total Bid
80 FLATS	EACH	675	$20.00	$13,500.00
81 1-GALLON	EACH	2,800	$5.00	$14,000.00
82 2-GALLON	EACH	98	$100.00	$9,800.00
83 5-GALLON	EACH	1,575	$10.00	$15,750.00
84 15-GALLON	EACH	18	$100.00	$1,800.00
85 15-GALLON CITRUS	EACH	62	$150.00	$9,300.00
86 24" BOX	EACH	138	$300.00	$41,400.00
87 36" BOX	EACH	7	$500.00	$3,500.00
88 48" BOX	EACH	1	$1,500.00	$1,500.00
89 6' BROWN TRUNK PALM	EACH	2	$1,000.00	$2,000.00
90 TREE GRATE	EACH	2	$3,000.00	$6,000.00
91 PICNIC TABLE	EACH	5	$1,500.00	$7,500.00
92 WASTE CONTAINER	EACH	9	$1,000.00	$9,000.00
93 FOUNTAIN	EACH	1	$1,000.00	$1,000.00
94 FLAG POLE	EACH	2	$5,000.00	$10,000.00
95 CONCRETE POT #13	EACH	4	$1,000.00	$4,000.00
96 CONCRETE POT #13A	EACH	8	$1,000.00	$8,000.00
97 CONCRETE POT #13B	EACH	4	$500.00	$2,000.00
98 CONCRETE BENCH #10	EACH	8	$750.00	$6,000.00
99 CONCRETE BENCH #15	EACH	6	$1,000.00	$6,000.00
100 LANDSCAPE MAINTENANCE	L.S.	1	$5,000.00	$5,000.00
101 ELECTRICAL LIGHTING FIXTURE A	EACH	24	$750.00	$18,000.00
102 ELECTRICAL LIGHTING FIXTURE B	EACH	2	$1,000.00	$2,000.00
103 ELECTRICAL LIGHTING FIXTURE C	EACH	5	$1,000.00	$5,000.00
104 ELECTRICAL LIGHTING FIXTURE D	EACH	9	$1,000.00	$9,000.00
105 ELECTRICAL LIGHTING FIXTURE E	EACH	4	$500.00	$2,000.00
106 ELECTRICAL CONDUIT AND WIRE	L.F.	4,450	$20.00	$89,000.00
				$3,820,227.00

Low Impact Development

The [redacted] employs a variety of Low Impact Development (LID) Best Management Practices (BMPs) at this facility. Instead of directing stormwater runoff from impervious surfaces (such as roofs and parking lots) to storm drains, it is directed to landscape features that collect the water and allow it to filter into the ground. BMPs help to:

- Recharge groundwater
- Reduce peak flows into the storm drain system, and by doing so, reduce erosion of local waterways
- Remove pollutants from stormwater runoff
- Reduce the cost of landscape upkeep and reduce the amount of water required for irrigation

Flows are collected and monitored for water quality improvements and stormwater volume reductions. BMP outflows will be compared to outflows from monitored control areas as well as to rainwater collected on-site. We hope to learn about the BMP performance, whether the operations and maintenance regimes specified in our LID Manuals need to be adjusted and how we can improve their design.

Throughout the facility, you will find informational signs that diagram and discuss in greater detail each BMP utilized at this facility. On the map in this brochure, the location of each sign is denoted by *.

[redacted]

[redacted]

[redacted]

Consultants

Civil Engineer, CValdo Corporation

Landscape Architect, RCB & Sons Corporation

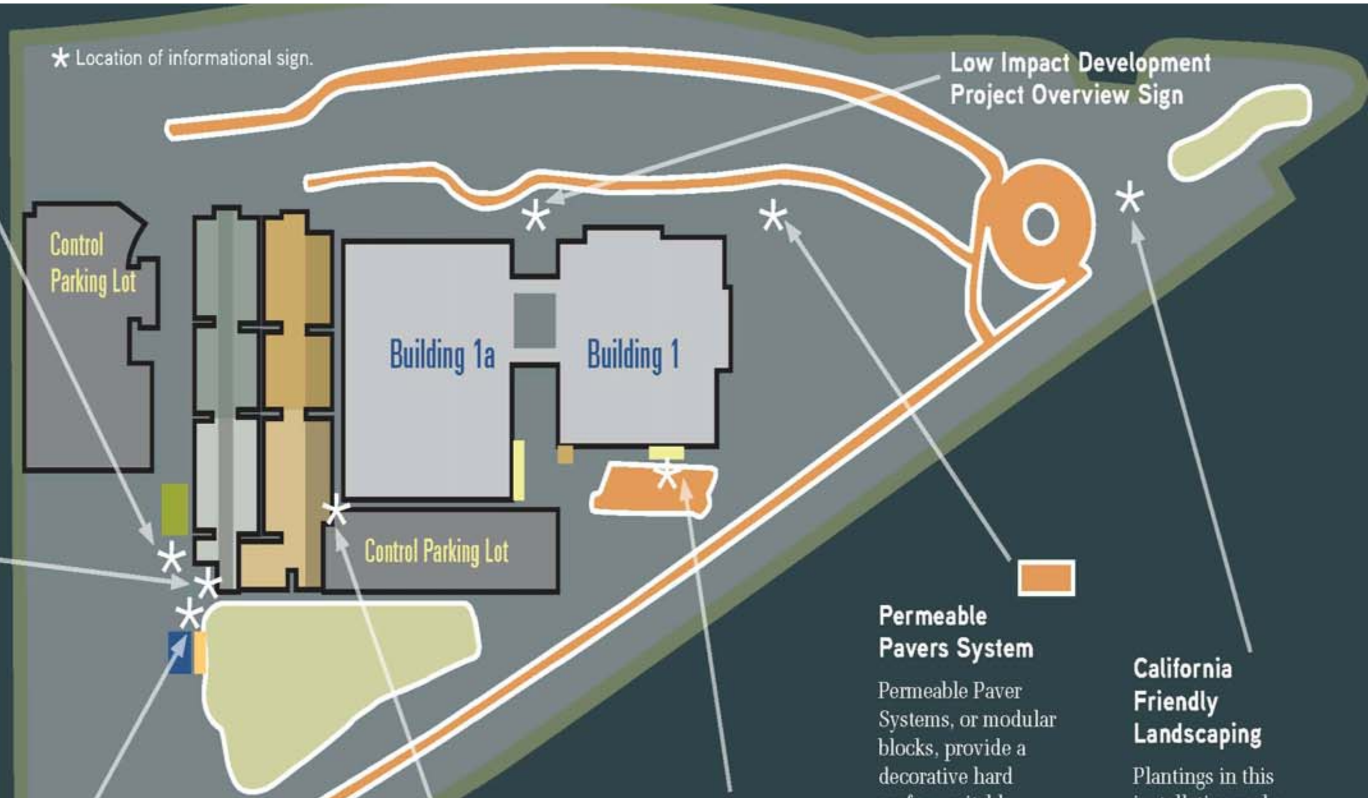
Contractor, ASR

Interpretive Elements Design, Watearth

Low Impact Development, Water Conservation Demonstration and Testing Facility

A walking guide to this facility

[redacted]



Bioretention

A depressed landscape feature captures rainfall and runoff. Retained water percolates through soil to a stone reservoir. Amended soil and plant roots act as a sponge, giving plants and their root structures longer time to absorb and evapotranspire water back into the atmosphere. The soil also filters debris and pollutants from the water.

Porous Asphalt

Although the parking stalls in this lot are paved in traditional asphalt, they slope toward a center strip that is surfaced with Porous Asphalt. Water passes freely through the Porous Asphalt to a stone reservoir.

Monitoring Station

Flows from the on-site BMPs will be monitored for water quality improvements as well as stormwater volume reductions. These flows will be compared to captured rainwater and flows from monitored control areas.

Porous Concrete

The parking stalls in this lot are paved with Porous Concrete. The rest of the parking lot is made of standard asphalt that drains into the Porous Concrete parking stalls. Water passes freely through the Porous Concrete to a stone reservoir.

Planter Box

Runoff from the roofs of each building are directed into Raised Planter Boxes filled with vegetation planted in an engineered soil mix. The soil acts as a filter that captures pollutants, allowing bacterial activity in the soil to metabolize trapped pollutants.

Permeable Pavers System

Permeable Paver Systems, or modular blocks, provide a decorative hard surface suitable for walkways and parking. The blocks, which are themselves impervious, are placed in such a way that gaps, filled with porous aggregate, are created. Stormwater passes through the gaps to a stone reservoir beneath the blocks. Stormwater infiltrates into the native soil over time.

California Friendly Landscaping

Plantings in this installation make use of California friendly plants that have evolved to live easily with our soils, wildlife and climate. Approximately 210 plant markers are distributed throughout the site. They highlight approximately 100 species of plants.

APPENDIX B

DOWNLOADED COST-ESTIMATING TOOL WORKSHEETS FROM WATER

ENVIRONMENT RESEARCH FOUNDATION

Extended Detention Basin

Site Name:

Site Location:

Design & Maintenance Options

WATERSHED CHARACTERISTICS	Unit	Model Default	User	Chosen option
Drainage Area (DA)	ac	10.00		10.00
Drainage Area Impervious Cover (IC)*	pct	40%		40%
Watershed Land Use Type *("R"-Residential; "C"-Commercial; "Ro"-Roads; "I"-Industrial)*		R		R

* Included since frequently used to calculate storage volume.

FACILITY STORAGE VOLUME	Unit	Model Default	User	Chosen Option
Water Quality Volume (WQV)*	ft^3	18,150		18,150
Flood Detention/Attenuation Volume	ft^3			0
Channel Protection/Erosion Control Volume**	ft^3			0
Other Volume (e.g., Recharge Volume)	ft^3			0
TOTAL FACILITY STORAGE VOLUME	ft^3		0	18,150

* Model default is 1/2-inch of capture over drainage area; actual volume will depend on regional regulatory requirements and site-specific characteristics, etc.

** For example, 24-hour extended detention storage.

DESIGN & MAINTENANCE OPTIONS	Unit	Model Default	User	Chosen Option
Choose Level of Maintenance *("H"=high; "M"=medium; "L"=low)*	-	M		M
Main Pool Volume	yd^3	672		672
Pct. Full when sediment removed from Basin*	pct	25%		25%
Quantity of Sediment Removed from Basin	yd^3	168		168

* Can adjust to be higher if expect heavy soils/sediment deposition to basin.

WHOLE LIFE COST OPTIONS	Unit	Model Default	User	Chosen Option
Discount Rate	%	5.50		5.5

Extended Detention Basin

CAPITAL COSTS

Choose Capital Costing Option

A	Total Facility Cost	$ 75,000

Site Name:
Site Location:

"A" - Simple Cost based on Drainage Area
"B" - User-Entered Engineer's Estimate

Method A: Simple Cost based on Drainage Area

Cost based on Drainage Area	Cost per Acre of DA Treated		(Chosen option)
	Model Default	User	
Drainage Area (DA) (acres)	10.00		10.00
Base Facility Cost per acre DA*	$ 3,000		$ 3,000
Default Cost Adjustment for Smaller Projects**	2.00		2.00
Resulting Base Cost per acre DA	$ 6,000		$ 6,000
Base Facility Cost (rounded up to nearest $100)	$ 60,000		**$ 60,000**
Engineering & Planning (default = 25% of Base Cost)	$ 15,000		$ 15,000
Land Cost	$ 0		$ 0
Other Costs	$ 0		$ 0
Total Associated Capital Costs (e.g., Engineering, Land, etc.)			**$ 15,000**
Total Facility Cost	**$ 75,000**		**$ 75,000**

*** Base Facility Cost guidelines (circa Year 2005)**
Very High = $15,000/acre
High = $5,000/acre
Medium = $3,000/acre
Low = $1,000/acre

** Smaller projects generally incur higher unit costs for many components; factor added to adjust.

Suggestion: Use higher or lower Base Costs to reflect higher or lower regional construction costs.
Some jurisdictions already have cost relationships established; check to see if any available.

Method B: User-Entered Engineer's Estimate

Select from the following list, as applicable to the project or facility type; add items where necessary.

Total Facility Base Costs	Unit	Unit Cost	Quantity	Cost
Mobilization	LS			$ -
Clearing & Grubbing	AC			$ -
Excavation/Embankment	CY			$ -
Dewatering	LS			$ -
Haul/Dispose of Excavated Material	CY			$ -
Sediment Pretreatment Struct. (e.g., inlet sump)	LF			$ -
Trash Rack	LF			$ -
Inflow Structure(s)	LS			$ -
Energy Dissipation Apron	LS			$ -
Outflow Structure	LS			$ -
Overflow Structure (concrete or rock riprap)	CY			$ -
Dam/Embankment	CY			$ -
Impermeable Liner	SY			$ -
Site Landscaping (e.g., trees)	LS			$ -
Maintenance Access Ramp/Pad	LS			$ -
Revegetation/Erosion Controls	SY			$ -
Traffic Control	LS			$ -
Amenity Items (e.g. recreational facilities, seating)	LS			$ -
Signage, Public Education Materials, etc.	LS			$ -
Other				$ -
Other				$ -
Other				$ -
Total Facility Base Cost				**$ -**
Associated Capital Costs	**Unit**	**Unit Cost**	**Quantity**	**Cost**
Project Management				$ -
Engineering: Preliminary				$ -
Engineering: Final Design				$ -
Topographic Survey				$ -
Geotechnical				$ -
Landscape Design				$ -
Land Acquisition (site, easements, etc.)				$ -
Utility Relocation				$ -
Legal Services				$ -
Permitting & Construction Inspection				$ -
Sales Tax				$ -
Contingency (e.g., 30%)				$ -
Total Associated Capital Costs				**$ -**
Total Facility Cost				**$ -**

Extended Detention Basin

M | **User entered MEDIUM maintenance level in Sheet 1.**

** Change on Sheet 1 if desired/applicable **

Site Name:

Site Location:

Maintenance Costs

User may enter lump sum here

Lookup ID	ROUTINE MAINTENANCE ACTIVITIES (Frequent, scheduled events)																					
	Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Inciden-tals Cost/Event ($)			Total cost per visit ($)		
		Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input
1.1	Inspection, Reporting & Information Management	36		36	2		2	1.0		1.0	40		40	30		30	0		0	140		140
1.2	Vegetation Management with Trash & Minor Debris Removal	12		12	4		4	2.0		2.0	30		30	60		60	0		0	480		480
1.3	Vector Control	36		36	0		0	1.0		1.0	40		40	200		200	200		200	200		200
1.4	*add additional activities if necessary*			0			0			0.0			0			0			0	0		0
1.5	*add additional activities if necessary*			0			0			0.0			0			0			0	0		0

Lookup ID	CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or > 3 yrs. betw. events)																					
	Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Inciden-tals Cost/Event ($)			Total cost per visit ($)		
		Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input
2.1	Intermittent Facility Maintenance (Excluding Sediment Removal)	12		12			0			0.0			0			0			0	1,000		1,000
2.2	*add additional activities if necessary*			0			0			0.0			0			0			0	0		0
2.3	*add additional activities if necessary*			0			0			0.0			0			0			0	0		0

Lookup ID	Cost Item	Frequency (months betw. maint. events)			Sediment Quantity (yds3) [from Sheet 1]			Cost per yd3 to Remove, Dispose of Sediment												Total cost per visit ($)		
		Model	User	Input	Model	User	Input	Model	User	Input										Model	User	Input
2.4	Sediment Removal	120		120	168		168	25.0		25.0										4,201		4,201
2.5	*add additional activities if necessary*			0			0			0.0										0		0
2.6	*add additional activities if necessary*			0			0			0.0										0		0

Note: For facilities judged to require larger or smaller amounts of maintenance (due to land area, etc.), consider multiplying the Model output in Column U by a multiplier (e.g., 120%) in Column V. Another quick means of adjustment would be to multiply the number of Hours per Event by a multiplier in the User Input field.

Lookup Table Value

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Lookup ID	HIGH, MEDIUM, AND LOW (MINIMUM) MAINTENANCE COST TABLES																					
	Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Inciden-tals Cost/Event ($)			Total cost per visit ($)		
		Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
1.0	ROUTINE MAINTENANCE ACTIVITIES (Frequent, scheduled)																					
1.1	Inspection, Reporting & Information Management	36	36	12	2	2	2	1.0	1.0	2.0	15.00	40.00	50.00	30	30	30	0	0	0	90	140	260
1.2	Vegetation Management with Trash & Minor Debris Removal	36	12	1	4	4	5	2.0	2.0	3.5	15.00	30.00	30.00	60	60	60	0	0	0	360	480	825
1.3	Vector Control	72	36	1	0	0	4	1.0	1.0	5.0	40.00	40.00	40.00	200	200	375	200	200	375	200	200	2,675
1.4	*add additional activities if necessary*																					
1.5	*add additional activities if necessary*																					
2.0	CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or > 3 yrs. betw. events)																					
2.1	Intermittent Facility Maintenance (Excluding Sediment Removal)	12	12	12																250	1,000	2,800
2.2	*add additional activities if necessary*																					
2.3	*add additional activities if necessary*																					
2.4	CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or > 3 yrs. betw. events)													Cost per Cubic Yard Disposal								
2.4	Sediment Removal	240	120	72	16	16	16	2.5	2.5	3.5	30.00	30.00	30.00	150	150	150	10	25	33	Function of quantity removed		
2.5	*add additional activities if necessary*																					
2.6	*add additional activities if necessary*																					

Extended Detention Basin

Site Name:
Site Location:

Cost Summary

CAPITAL COSTS	Included in WLC Calculation			Total Cost	
	Model	User	Chosen option		
Total Facility Base Cost	Y		Y		$60,000
Total Associated Capital Costs (e.g., Engineering, Land, etc.)	Y		Y		$15,000
Capital Costs	Y		Y		**$75,000**

REGULAR MAINTENANCE ACTIVITIES	Included in WLC Calculation			Years between Events	Cost per Event	Total Cost per Year
	Model	User	Chosen option			
Inspection, Reporting & Information Management	Y		Y	3	$140	$47
Vegetation Management with Trash & Minor Debris Removal	Y		Y	1	$480	$480
Vector Control	Y		Y	3	$200	$67
add additional activities if necessary	Y		Y	0	$0	$0
add additional activities if necessary	Y		Y	0	$0	$0
Totals, Regular Maintenance Activities						**$593**

CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or >3yrs. betw. events)	Included in WLC			Years between Events	Cost per Event	Total Cost per Year
	Model	User	Chosen option			
Intermittent Facility Maintenance (Excluding Sediment Removal)	Y		Y	1	$1,000	$1,000
Sediment Removal	Y		Y	10	$4,201	$420
add additional activities if necessary	Y		Y	0	$0	$0
add additional activities if necessary	Y		Y	0	$0	$0
add additional activities if necessary	Y		Y	0	$0	$0
add additional activities if necessary	Y		Y	0	$0	$0
Totals, Corrective & Infrequent Maintenance Activities						**$1,420**

Extended Detention Basin

Site Name:
Site Location:

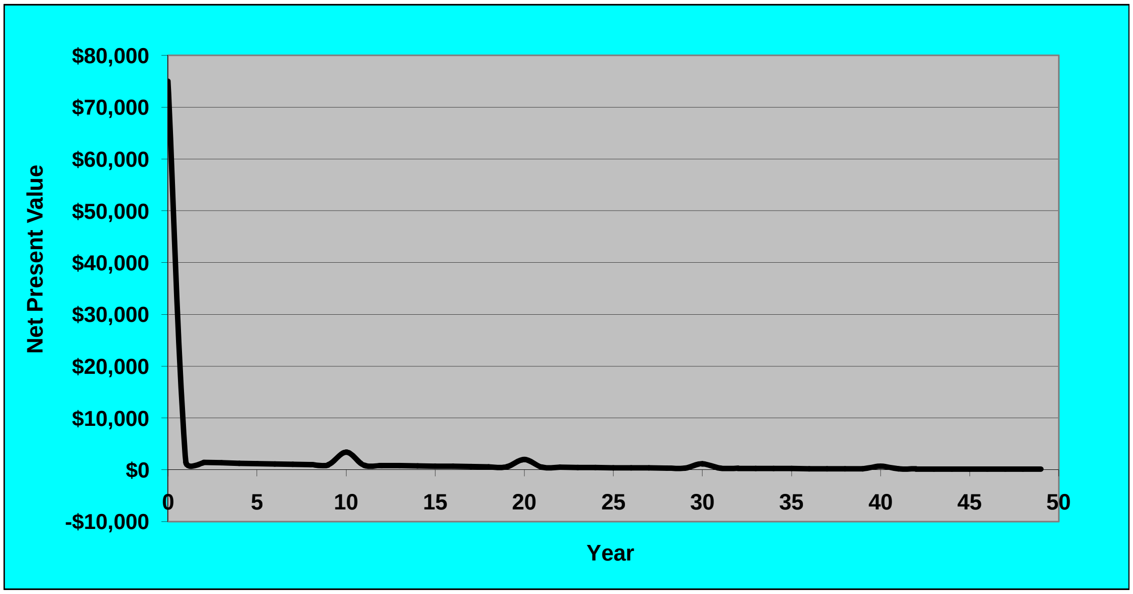
Whole Life Costs

Year	Discount Factor	Capital & Assoc. Costs	Regular Maint. Costs	Corrective & Infrequent Maint. Activities				Total Costs	Present Value of Costs	Cumulative Costs	
				Intermit. Facility Maint.	Sediment Removal	Other [User Entered]	Total Irregular Maint.			Cash	Present Value
Cash Sum ($)								$ 169,879	$ 107,104		
0	1.000	$ 75,000						$ 75,000	$ 75,000	$ 75,000	$ 75,000
1	0.948	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 1,510	$ 76,593	$ 76,510
2	0.898	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 1,432	$ 78,187	$ 77,942
3	0.852	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 1,357	$ 79,780	$ 79,299
4	0.807	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 1,286	$ 81,373	$ 80,585
5	0.765	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 1,219	$ 82,967	$ 81,804
6	0.725	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 1,156	$ 84,560	$ 82,960
7	0.687	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 1,095	$ 86,153	$ 84,055
8	0.652	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 1,038	$ 87,747	$ 85,093
9	0.618	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 984	$ 89,340	$ 86,077
10	0.585	$ -	$ 593	$ 1,000	$ 4,201	$ -	$ 5,201	$ 5,795	$ 3,392	$ 95,135	$ 89,470
11	0.555	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 884	$ 96,728	$ 90,354
12	0.526	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 838	$ 98,321	$ 91,192
13	0.499	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 794	$ 99,915	$ 91,986
14	0.473	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 753	$ 101,508	$ 92,739
15	0.448	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 714	$ 103,101	$ 93,453
16	0.425	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 676	$ 104,695	$ 94,129
17	0.402	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 641	$ 106,288	$ 94,771
18	0.381	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 608	$ 107,881	$ 95,378
19	0.362	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 576	$ 109,475	$ 95,954
20	0.343	$ -	$ 593	$ 1,000	$ 4,201	$ -	$ 5,201	$ 5,795	$ 1,986	$ 115,269	$ 97,941
21	0.325	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 518	$ 116,863	$ 98,458
22	0.308	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 491	$ 118,456	$ 98,949
23	0.292	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 465	$ 120,049	$ 99,414
24	0.277	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 441	$ 121,643	$ 99,855
25	0.262	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 418	$ 123,236	$ 100,272
26	0.249	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 396	$ 124,829	$ 100,668
27	0.236	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 375	$ 126,423	$ 101,044
28	0.223	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 356	$ 128,016	$ 101,400
29	0.212	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 337	$ 129,609	$ 101,737
30	0.201	$ -	$ 593	$ 1,000	$ 4,201	$ -	$ 5,201	$ 5,795	$ 1,163	$ 135,404	$ 102,900
31	0.190	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 303	$ 136,998	$ 103,203
32	0.180	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 287	$ 138,591	$ 103,490
33	0.171	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 272	$ 140,184	$ 103,762
34	0.162	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 258	$ 141,778	$ 104,020
35	0.154	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 245	$ 143,371	$ 104,265
36	0.146	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 232	$ 144,964	$ 104,497
37	0.138	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 220	$ 146,558	$ 104,716
38	0.131	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 208	$ 148,151	$ 104,925
39	0.124	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 197	$ 149,744	$ 105,122
40	0.117	$ -	$ 593	$ 1,000	$ 4,201	$ -	$ 5,201	$ 5,795	$ 681	$ 155,539	$ 105,803
41	0.111	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 177	$ 157,132	$ 105,980
42	0.106	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 168	$ 158,726	$ 106,148
43	0.100	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 159	$ 160,319	$ 106,308
44	0.095	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 151	$ 161,912	$ 106,459
45	0.090	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 143	$ 163,506	$ 106,602
46	0.085	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 136	$ 165,099	$ 106,738
47	0.081	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 129	$ 166,692	$ 106,866
48	0.077	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 122	$ 168,286	$ 106,988
49	0.073	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 116	$ 169,879	$ 107,104
50	0.069	$ 1	$ 593	$ 1,000	$ 4,201	$ -	$ 5,201	$ 5,796	$ 399	$ 175,675	$ 107,503

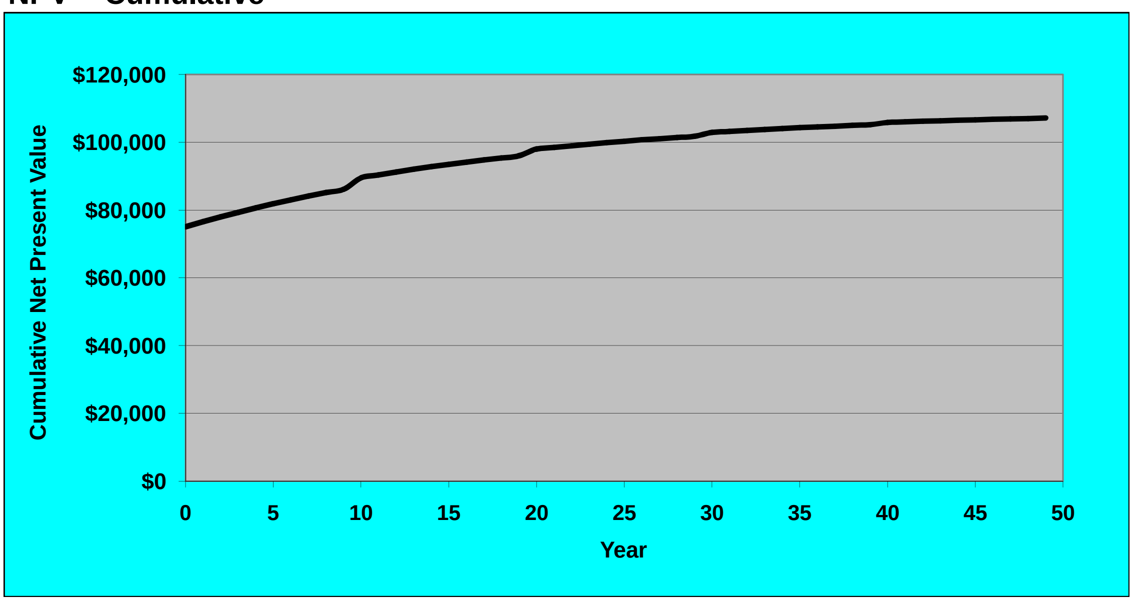
Extended Detention Basin

Site Name:
Site Location:

Net Present Value over time



NPV - Cumulative



Permeable Pavement

Site Name:

Site Location:

Design & Maintenance Options

WATERSHED CHARACTERISTICS	Unit	Model Default	User	Chosen option
Surface Area of Permeable Pavement System	ft2	21,780		21,780
Drainage Area (DA)	ft2	21,780		21,780
Drainage Area Impervious Cover (IC)*	pct	100%		100%
Watershed Land Use Type *("R"-Residential; "C"-Commercial; "Ro"-Roads; "I"-Industrial)*		R		R

* Included since frequently used to calculate facility sizing.

DESIGN & MAINTENANCE OPTIONS	Unit	Model Default	User	Chosen Option
Choose among the following (affects default cost calcs):	-	1		1
1. Asphalt	User Selected Pavement Type = **Asphalt**			
2. Porous Concrete				
3. Grass / Gravel Pavers				
4. Interlocking Concrete Paving Blocks				
5. Other				
Choose Capital Cost Level *("H"=high; "L"=low)*	-	H		H
Choose Level of Maintenance *("H"=high; "M"=medium; "L"=low)*	-	M		M

WHOLE LIFE COST OPTIONS	Unit	Model Default	User	Chosen Option
Discount Rate	%	5.50		5.5

Permeable Pavement

CAPITAL COSTS

Site Name:
Site Location:

Choose Capital Costing Option

A	Total Facility Cost	$ 28,780

"A" - Simple Cost based on System Type
"B" - User-Entered Engineer's Estimate

Method A: Simple Cost based on Drainage Area

Cost based on Drainage Area	Cost per Acre of DA Treated		(Chosen option)
	Model Default	User	
User Selected **ASPHALT** Permeable Pavement		Entered Sheet 1	1
Surface Area of Permeable Pavement System (ft2)		Entered Sheet 1	21,780
User Selected HIGH Permeable Pavement		Entered Sheet 1	H
Permeable Pavement Cost per square foot	$1.00		$1.00
Base Facility Cost (rounded up to nearest $100)	$ 21,800		**$ 21,800**
Engineering & Planning (default = 10% of Base Cost)	$ 2,180		$ 2,180
Land Cost	$ 0		$ 0
Other Costs	$ 0		$ 0
Contingency (default = 20%, rounded up to nearest $100)	$ 4,800		$ 4,800
Total Associated Capital Costs (e.g., Engineering, Land, etc.)			**$ 6,980**
Total Facility Cost	**$ 23,980**		**$ 28,780**

Suggestion: Use higher or lower Per Unit Costs to reflect higher or lower regional construction costs.

Method B: User-Entered Engineer's Estimate

Select from the following list, as applicable to the project or facility type; add items where necessary.

Total Facility Base Costs	Unit	Unit Cost	Quantity	Cost
Mobilization	LS			$ -
Clearing & Grubbing	AC			$ -
Excavation/Grading	CY			$ -
Haul/Dispose of Excavated Material	CY			$ -
Subsoil Preparation	SY			$ -
Impermeable Liner	SY			$ -
Rock Media	SY			$ -
Permeable Media	SF			$ -
Outflow Structure/Pipe	LS			$ -
Energy Dissipation Apron	LS			$ -
Revegetation/Erosion Controls	SY			$ -
Traffic Control	LS			$ -
Signage, Public Education Materials, etc.	LS			$ -
Other				$ -
Other				$ -
Total Facility Base Cost				**$ -**
Associated Capital Costs	**Unit**	**Unit Cost**	**Quantity**	**Cost**
Project Management				$ -
Engineering: Preliminary				$ -
Engineering: Final Design				$ -
Topographic Survey				$ -
Geotechnical				$ -
Landscape Design				$ -
Land Acquisition (site, easements, etc.)				$ -
Utility Relocation				$ -
Legal Services				$ -
Permitting & Construction Inspection				$ -
Sales Tax				$ -
Contingency (e.g., 30%)				$ -
Total Associated Capital Costs				**$ -**
Total Facility Cost				**$ -**

Permeable Pavement

M | **User entered MEDIUM maintenance level in Sheet 1.**

** Change on Sheet 1 if desired/applicable **

Site Name:

Site Location:

Maintenance Costs

User may enter lump sum here

Lookup ID	ROUTINE MAINTENANCE ACTIVITIES (Frequent, scheduled events)																					
	Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Inciden-tals Cost/Event ($)			Total cost per visit ($)		
		Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input
1.1	Inspection, Reporting & Information Management	36		**36**	2		**2**	1.0		**1.0**	40		**40**	30		**30**	0		**0**	**140**		**140**
1.2	Litter & Minor Debris Removal	12		**12**	2		**2**	1.0		**1.0**	30		**30**	30		**30**	0		**0**	**120**		**120**
1.3	Permeable pavement sweeping	12		**12**	1		**1**	1.0		**1.0**	20		**20**	60		**60**	0		**0**	**80**		**80**
1.4	*Additional activities*			**0**			**0**			**0.0**			**0**			**0**			**0**	**0**		**0**
1.5	*Additional activities*			**0**			**0**			**0.0**			**0**			**0**			**0**	**0**		**0**

Lookup ID	CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or > 3 yrs. betw. events)																					
	Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Inciden-tals Cost/Event ($)			Total cost per visit ($)		
		Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input
2.1	Intermittent facility maintenance	0		**0**	0		**0**	0.0		**0.0**	0		**0**	0		**0**	0		**0**	**0**		**0**
2.2	Remove existing pavement & aggregate; wash and/or replace & reinstall*	420		**420**	0		**0**	0.0		**0.0**	0		**0**	0		**0**	21,800		**21,800**	**21,800**		**21,800**
2.3	*Additional activities*			**0**			**0**			**0.0**			**0**			**0**			**0**	**0**		**0**
2.4	*Additional activities*			**0**			**0**			**0.0**			**0**			**0**			**0**	**0**		**0**

* Removal and reinstallation assumes entire base cost of initial construction incurred. Needs better data corroboration.

Note: For facilities judged to require larger or smaller amounts of maintenance (due to land area, etc.), consider multiplying the Model output in Column U by a multiplier (e.g., 120%) in Column V. Another quick means of adjustment would be to multiply the number of Hours per Event by a multiplier in the User Input field.

Lookup Table Value

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Lookup ID	HIGH, MEDIUM, AND LOW (MINIMUM) MAINTENANCE COST TABLES																					
	Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Inciden-tals Cost/Event ($)			Total cost per visit ($)		
		Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
1.0	**ROUTINE MAINTENANCE ACTIVITIES (Frequent, scheduled)**																					
1.1	Inspection, Reporting & Information Management	36	36	12	2	2	2	1.0	1.0	2.0	15.00	40.00	50.00	30	30	30	0	0	0	**90**	**140**	**260**
1.2	Litter & Minor Debris Removal	36	12	1	1	2	2	1.0	1.0	1.0	15.00	30.00	30.00	30	30	30	0	0	0	**45**	**120**	**120**
1.3	Permeable pavement sweeping	36	12	1	2	1	1	1.0	1.0	1.0	20.00	20.00	20.00	60	60	60	0	0	0	**160**	**80**	**80**
1.4	*Additional activities*																					
1.5	*Additional activities*																					
2.0	**CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or > 3 yrs. betw. events)**													**Cost per Cubic Yard Disposal**								
2.1	Intermittent facility maintenance																			**No data**	**No data**	**No data**
2.2	Remove existing pavement & aggregate; wash and/or replace & reinstall*	540	420	300													21,800	21,800	21,800	**21,800**	**21,800**	**21,800**
2.3	*Additional activities*																			**No data**	**No data**	**No data**
2.4	*Additional activities*																			**No data**	**No data**	**No data**

* Removal and reinstallation assumes entire base cost of initial construction incurred. Needs better data corroboration.

Permeable Pavement

Site Name:
Site Location:

Cost Summary

CAPITAL COSTS	Included in WLC Calculation			Total Cost	
	Model	User	Chosen option		
Total Facility Base Cost	Y		Y		$21,800
Total Associated Capital Costs (e.g., Engineering, Land, etc.)	Y		Y		$2,180
Capital Costs	Y		Y		**$28,780**

REGULAR MAINTENANCE ACTIVITIES	Included in WLC Calculation			Years between Events	Cost per Event	Total Cost per Year
	Model	User	Chosen option			
Inspection, Reporting & Information Management	Y		Y	3	$140	$47
Litter & Minor Debris Removal	Y		Y	1	$120	$120
Permeable pavement sweeping	Y		Y	1	$80	$80
Additional activities	Y		Y	0	$0	$0
Additional activities	Y		Y	0	$0	$0
Totals, Regular Maintenance Activities						**$247**

CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or >3yrs. betw. events)	Included in WLC			Years between Events	Cost per Event	Total Cost per Year
	Model	User	Chosen option			
Intermittent facility maintenance	Y		Y	0	$0	$0
Remove existing pavement & aggregate; wash and/or replace & reinstall*	Y		Y	35	$21,800	$623
Additional activities	Y		Y	0	$0	$0
Additional activities	Y		Y	0	$0	$0
Totals, Corrective & Infrequent Maintenance Activities						**$623**

Permeable Pavement

Site Name:
Site Location:

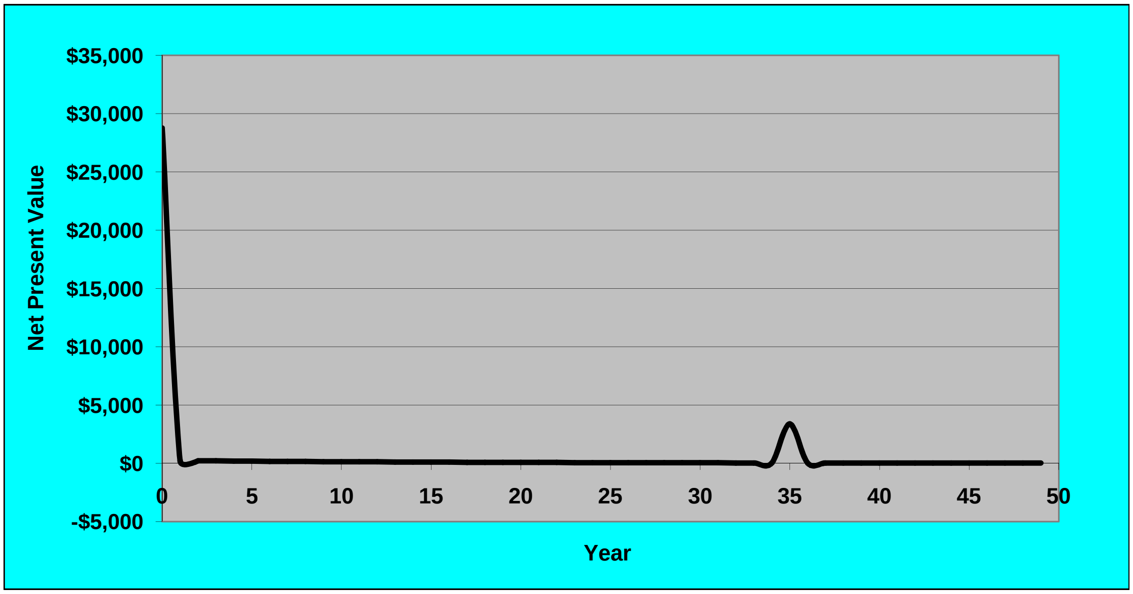
Whole Life Costs

Year	Discount Factor	Capital & Assoc. Costs	Regular Maint. Costs	Corrective Maint.	Total Costs	Present Value of Costs	Cumulative Costs	
							Cash	Present Value
Cash Sum ($)					**$ 62,667**	**$ 36,286**		
0	1.000	**$ 28,780**			$ 28,780	$ 28,780	$ 28,780	$ 28,780
1	0.948	$ -	**$ 247**	$ -	$ 247	$ 234	$ 29,027	$ 29,014
2	0.898	$ -	$ 247	$ -	$ 247	$ 222	$ 29,273	$ 29,235
3	0.852	$ -	$ 247	$ -	$ 247	$ 210	$ 29,520	$ 29,445
4	0.807	$ -	$ 247	$ -	$ 247	$ 199	$ 29,767	$ 29,645
5	0.765	$ -	$ 247	$ -	$ 247	$ 189	$ 30,013	$ 29,833
6	0.725	$ -	$ 247	$ -	$ 247	$ 179	$ 30,260	$ 30,012
7	0.687	$ -	$ 247	$ -	$ 247	$ 170	$ 30,507	$ 30,182
8	0.652	$ -	$ 247	$ -	$ 247	$ 161	$ 30,753	$ 30,343
9	0.618	$ -	$ 247	$ -	$ 247	$ 152	$ 31,000	$ 30,495
10	0.585	$ -	$ 247	$ -	$ 247	$ 144	$ 31,247	$ 30,639
11	0.555	$ -	$ 247	$ -	$ 247	$ 137	$ 31,493	$ 30,776
12	0.526	$ -	$ 247	$ -	$ 247	$ 130	$ 31,740	$ 30,906
13	0.499	$ -	$ 247	$ -	$ 247	$ 123	$ 31,987	$ 31,029
14	0.473	$ -	$ 247	$ -	$ 247	$ 117	$ 32,233	$ 31,145
15	0.448	$ -	$ 247	$ -	$ 247	$ 110	$ 32,480	$ 31,256
16	0.425	$ -	$ 247	$ -	$ 247	$ 105	$ 32,727	$ 31,361
17	0.402	$ -	$ 247	$ -	$ 247	$ 99	$ 32,973	$ 31,460
18	0.381	$ -	$ 247	$ -	$ 247	$ 94	$ 33,220	$ 31,554
19	0.362	$ -	$ 247	$ -	$ 247	$ 89	$ 33,467	$ 31,643
20	0.343	$ -	$ 247	$ -	$ 247	$ 85	$ 33,713	$ 31,728
21	0.325	$ -	$ 247	$ -	$ 247	$ 80	$ 33,960	$ 31,808
22	0.308	$ -	$ 247	$ -	$ 247	$ 76	$ 34,207	$ 31,884
23	0.292	$ -	$ 247	$ -	$ 247	$ 72	$ 34,453	$ 31,956
24	0.277	$ -	$ 247	$ -	$ 247	$ 68	$ 34,700	$ 32,024
25	0.262	$ -	$ 247	$ -	$ 247	$ 65	$ 34,947	$ 32,089
26	0.249	$ -	$ 247	$ -	$ 247	$ 61	$ 35,193	$ 32,150
27	0.236	$ -	$ 247	$ -	$ 247	$ 58	$ 35,440	$ 32,208
28	0.223	$ -	$ 247	$ -	$ 247	$ 55	$ 35,687	$ 32,263
29	0.212	$ -	$ 247	$ -	$ 247	$ 52	$ 35,933	$ 32,315
30	0.201	$ -	$ 247	$ -	$ 247	$ 49	$ 36,180	$ 32,365
31	0.190	$ -	$ 247	$ -	$ 247	$ 47	$ 36,427	$ 32,412
32	0.180	$ -	$ 247	$ -	$ 247	$ 44	$ 36,673	$ 32,456
33	0.171	$ -	$ 247	$ -	$ 247	$ 42	$ 36,920	$ 32,499
34	0.162	$ -	$ 247	$ -	$ 247	$ 40	$ 37,167	$ 32,538
35	0.154	$ -	$ 247	$ 21,800	$ 22,047	$ 3,385	$ 59,213	$ 35,923
36	0.146	$ -	$ 247	$ -	$ 247	$ 36	$ 59,460	$ 35,959
37	0.138	$ -	$ 247	$ -	$ 247	$ 34	$ 59,707	$ 35,993
38	0.131	$ -	$ 247	$ -	$ 247	$ 32	$ 59,953	$ 36,025
39	0.124	$ -	$ 247	$ -	$ 247	$ 31	$ 60,200	$ 36,056
40	0.117	$ -	$ 247	$ -	$ 247	$ 29	$ 60,447	$ 36,085
41	0.111	$ -	$ 247	$ -	$ 247	$ 27	$ 60,693	$ 36,112
42	0.106	$ -	$ 247	$ -	$ 247	$ 26	$ 60,940	$ 36,138
43	0.100	$ -	$ 247	$ -	$ 247	$ 25	$ 61,187	$ 36,163
44	0.095	$ -	$ 247	$ -	$ 247	$ 23	$ 61,433	$ 36,186
45	0.090	$ -	$ 247	$ -	$ 247	$ 22	$ 61,680	$ 36,209
46	0.085	$ -	$ 247	$ -	$ 247	$ 21	$ 61,927	$ 36,230
47	0.081	$ -	$ 247	$ -	$ 247	$ 20	$ 62,173	$ 36,249
48	0.077	$ -	$ 247	$ -	$ 247	$ 19	$ 62,420	$ 36,268
49	0.073	$ -	$ 247	$ -	$ 247	$ 18	$ 62,667	$ 36,286
50	0.069	$ 1	$ 247	$ -	$ 248	$ 17	$ 62,914	$ 36,303

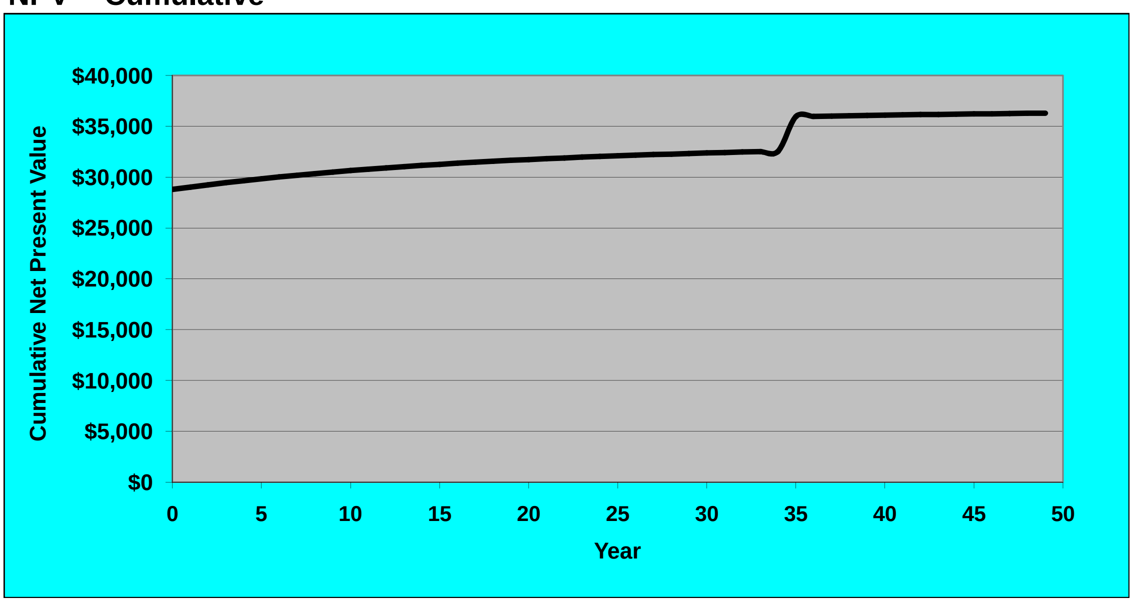
Permeable Pavement

Site Name:
Site Location:

Net Present Value over time



NPV - Cumulative



Retention Pond

Site Name:

Site Location:

Design & Maintenance Options

WATERSHED CHARACTERISTICS	Unit	Model Default	User	Chosen option
Drainage Area (DA)	ac	50.00	50.00	50.00
Drainage Area Impervious Cover (IC)*	pct	40%		40%
Watershed Land Use Type *("R"-Residential; "C"-Commercial; "Ro"-Roads; "I"-Industrial)*		R		R

* Included since frequently used to calculate storage volume.

FACILITY STORAGE VOLUME	Unit	Model Default	User	Chosen Option
Water Quality Volume (WQV)*	ft^3	90,750		90,750
Permanent Pool Volume as Ratio of Water Quality Volume**	ratio	1.00		1.00
Permanent Pool Volume	ft^3	90,750	90,750	90,750
Flood Detention/Attenuation Volume	ft^3			0
Channel Protection/Erosion Control Volume***	ft^3			0
Other Volume (e.g., Recharge Volume)	ft^3			0
TOTAL FACILITY STORAGE VOLUME	ft^3		**90,750**	**90,750**

* Model default is 1/2-inch of capture over drainage area; actual volume will depend on regional regulatory requirements and site-specific characteristics, etc.

** Model default ratio = 1.0 (i.e., permanent pool volume EQUALS the water quality volume).

*** For example, 24-hour extended detention storage.

DESIGN & MAINTENANCE OPTIONS	Unit	Model Default	User	Chosen Option
Choose Level of Maintenance *("H"=high; "M"=medium; "L"=low)*	-	M		M
Forebay Size (Pct. of Total Pool) [**Enter 0% if no forebay** or if not maintained separately from main pool]*	pct	0%		0%
Forebay Volume	yd^3	0		0
Main Pool Volume	yd^3	3,361		3,361
Pct. Full when sediment removed from Forebay/Main Pool**	pct	25%		25%
Quantity of Sediment Removed from Forebay	yd^3	0		0
Quantity of Sediment Removed from Main Pool	yd^3	840		840

* Model default is no separate maintenance of the forebay.

** Can adjust to be higher if expect heavy soils/sediment deposition to basin.

WHOLE LIFE COST OPTIONS	Unit	Model Default	User	Chosen Option
Discount Rate	%	5.50		5.5

Retention Pond

CAPITAL COSTS

Site Name:
Site Location:

Choose Capital Costing Option

A	Total Facility Cost	$ 266,250

"A" - Simple Cost based on Drainage Area
"B" - User-Entered Engineer's Estimate

Method A: Simple Cost based on Drainage Area

Cost based on Drainage Area	Cost per Acre of DA Treated		(Chosen option)
	Model Default	User	
Drainage Area (DA) (acres)	50.00		50.00
Base Facility Cost per acre DA*	$ 3,000		$ 3,000
Default Cost Adjustment for Smaller Projects**	1.42		1.42
Resulting Base Cost per acre DA	$ 4,260		$ 4,260
Base Facility Cost (rounded up to nearest $100)	$ 213,000		**$ 213,000**
Engineering & Planning (default = 25% of Base Cost)	$ 53,250		$ 53,250
Land Cost	$ 0		$ 0
Other Costs	$ 0		$ 0
Total Associated Capital Costs (e.g., Engineering, Land, etc.)			**$ 53,250**
Total Facility Cost	**$ 266,250**		**$ 266,250**

*** Base Facility Cost guidelines (circa Year 2005)**
Very High = $15,000/acre
High = $5,000/acre
Medium = $3,000/acre
Low = $1,000/acre

** Smaller projects generally incur higher unit costs for many components; factor added to adjust.

Suggestion: Use higher or lower Base Costs to reflect higher or lower regional construction costs.
Some jurisdictions already have cost relationships established; check to see if any available.

Method B: User-Entered Engineer's Estimate

Select from the following list, as applicable to the project or facility type; add items where necessary.

Total Facility Base Costs	Unit	Unit Cost	Quantity	Cost
Mobilization	LS			$ -
Clearing & Grubbing	AC			$ -
Excavation/Embankment	CY			$ -
Dewatering	LS			$ -
Haul/Dispose of Excavated Material	CY			$ -
Sediment Pretreatment Struct. (e.g., inlet sump)	LF			$ -
Trash Rack	LF			$ -
Inflow Structure(s)	LS			$ -
Energy Dissipation Apron	LS			$ -
Outflow Structure	LS			$ -
Overflow Structure (concrete or rock riprap)	CY			$ -
Dam/Embankment	CY			$ -
Impermeable Liner	SY			$ -
Water's Edge Vegetation	SF			$ -
Wetlands Vegetation	SF			$ -
Site Landscaping (e.g., trees)	LS			$ -
Maintenance Access Ramp/Pad	LS			$ -
Revegetation/Erosion Controls	SY			$ -
Traffic Control	LS			$ -
Amenity Items (e.g. recreational facilities, seating)	LS			$ -
Signage, Public Education Materials, etc.	LS			$ -
Other				$ -
Other				$ -
Other				$ -
Total Facility Base Cost				**$ -**

Associated Capital Costs	Unit	Unit Cost	Quantity	Cost
Project Management				$ -
Engineering: Preliminary				$ -
Engineering: Final Design				$ -
Topographic Survey				$ -
Geotechnical				$ -
Landscape Design				$ -
Land Acquisition (site, easements, etc.)				$ -
Utility Relocation				$ -
Legal Services				$ -
Permitting & Construction Inspection				$ -
Sales Tax				$ -
Contingency (e.g., 30%)				$ -
Total Associated Capital Costs				**$ -**
Total Facility Cost				**$ -**

Retention Pond

M **User entered MEDIUM maintenance level in Sheet 1.**

** Change on Sheet 1 if desired/applicable **

Site Name:

Site Location:

Maintenance Costs

User may enter lump sum here*

ROUTINE MAINTENANCE ACTIVITIES (Frequent, scheduled events)

Lookup ID	Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Inciden-tals Cost/Event ($)			Total cost per visit ($)		
		Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input
1.1	Inspection, Reporting & Information Management	36		**36**	2		**2**	1.0		**1.0**	40		**40**	30		**30**	0		**0**	**140**		**140**
1.2	Vegetation Management with Trash & Minor Debris Removal	12		**12**	4		**4**	2.0		**2.0**	30		**30**	60		**60**	0		**0**	**480**		**480**
1.3	Vector Control	36		**36**	0		**0**	1.0		**1.0**	40		**40**	200		**200**	200		**200**	**200**		**200**
1.4	*add additional activities if necessary*	0		**0**	0		**0**	0.0		**0.0**	0		**0**	0		**0**	0		**0**	**0**		**0**
1.5	*add additional activities if necessary*	0		**0**	0		**0**	0.0		**0.0**	0		**0**	0		**0**	0		**0**	**0**		**0**

CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or > 3 yrs. betw. events)

Lookup ID	Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Inciden-tals Cost/Event ($)			Total cost per visit ($)		
		Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input
2.1	Intermittent Facility Maintenance (Excluding Sediment Removal)	12		**12**			**0**			**0.0**			**0**			**0**			**0**	**1,000**		**1,000**
2.2	*add additional activities if necessary*			**0**			**0**			**0.0**			**0**			**0**			**0**	**0**		**0**
2.3	*add additional activities if necessary*			**0**			**0**			**0.0**			**0**			**0**			**0**	**0**		**0**

Lookup ID	Cost Item	Frequency (months betw. maint. events)			Sediment Quantity (yds3) [from Sheet 1]			Cost per yd3 to Remove, Dispose of Sediment												Total cost per visit ($)		
		Model	User	Input	Model	User	Input	Model	User	Input										Model	User	Input
2.4	Sediment Dewatering & Removal: Forebay	96		**96**	0		**0**	50.0		**50.0**										**0**		**0**
2.5	Sediment Dewatering & Removal: Main Pool	240		**240**	840		**840**	50.0		**50.0**										**42,014**		**42,014**
2.6	*add additional activities if necessary*			**0**			**0**			**0.0**										**0**		**0**
2.7	*add additional activities if necessary*			**0**			**0**			**0.0**										**0**		**0**

*** Note: For facilities judged to require larger or smaller amounts of maintenance (due to land area, etc.), consider multiplying the Model output in Column U by a multiplier (e.g., 120%) in Column V. Another quick means of adjustment would be to multiply the number of Hours per Event by a multiplier in the User Input field.**

Lookup Table Value

HIGH, MEDIUM, AND LOW (MINIMUM) MAINTENANCE COST TABLES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Lookup ID	Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Inciden-tals Cost/Event ($)			Total cost per visit ($)		
		Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
1.0	ROUTINE MAINTENANCE ACTIVITIES (Frequent, scheduled)																					
1.1	Inspection, Reporting & Information Management	36	36	12	2	2	2	1.0	1.0	2.0	15.00	40.00	50.00	30	30	30	0	0	0	**90**	**140**	**260**
1.2	Vegetation Management with Trash & Minor Debris Removal	36	12	1	4	4	8	2.0	2.0	5.0	15.00	30.00	30.00	60	60	60	0	0	0	**360**	**480**	**1,680**
1.3	Vector Control	72	36	1	0	0	4	1.0	1.0	5.0	40.00	40.00	40.00	200	200	375	200	200	375	**200**	**200**	**2,675**
1.4	*add additional activities if necessary*																					
1.5	*add additional activities if necessary*																					
2.0	CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or > 3 yrs. betw. events)																					
2.1	Intermittent Facility Maintenance (Excluding Sediment Removal)	12	12	12																**500**	**1,000**	**3,400**
2.2	*add additional activities if necessary*																					
2.3	*add additional activities if necessary*																					
2.4	CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or > 3 yrs. betw. events)														Cost per Cubic Yard Disposal							
2.4	Sediment Dewatering & Removal: Forebay	240	96	24	4	4	4	2.5	2.5	2.5	30.00	30.00	30.00	150	150	150	20	50	65	**Function of quantity removed**		
2.5	Sediment Dewatering & Removal: Main Pool	480	240	120	16	16	16	2.5	2.5	4.5	30.00	30.00	30.00	150	150	150	20	50	65			
2.6	*add additional activities if necessary*																					
2.7	*add additional activities if necessary*																					

Retention Pond

Site Name:
Site Location:

Cost Summary

CAPITAL COSTS	Included in WLC Calculation			Total Cost	
	Model	User	Chosen option		
Total Facility Base Cost	Y		Y		$213,000
Total Associated Capital Costs (e.g., Engineering, Land, etc.)	Y		Y		$53,250
Capital Costs	Y		Y		**$266,250**

REGULAR MAINTENANCE ACTIVITIES	Included in WLC Calculation			Years between Events	Cost per Event	Total Cost per Year
	Model	User	Chosen option			
Inspection, Reporting & Information Management	Y		Y	3	$140	$47
Vegetation Management with Trash & Minor Debris Removal	Y		Y	1	$480	$480
Vector Control	Y		Y	3	$200	$67
add additional activities if necessary	Y		Y	0	$0	$0
add additional activities if necessary	Y		Y	0	$0	$0
Totals, Regular Maintenance Activities						**$593**

CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or >3yrs. betw. events)	Included in WLC			Years between Events	Cost per Event	Total Cost per Year
	Model	User	Chosen option			
Intermittent Facility Maintenance (Excluding Sediment Removal)	Y		Y	1	$1,000	$1,000
Sediment Dewatering & Removal: Forebay	Y		Y	8	$0	$0
Sediment Dewatering & Removal: Main Pool	Y		Y	20	$42,014	$2,101
add additional activities if necessary	Y		Y	0	$0	$0
add additional activities if necessary	Y		Y	0	$0	$0
add additional activities if necessary	Y		Y	0	$0	$0
add additional activities if necessary	Y		Y	0	$0	$0
Totals, Corrective & Infrequent Maintenance Activities						**$3,101**

Retention Pond

Site Name:
Site Location:

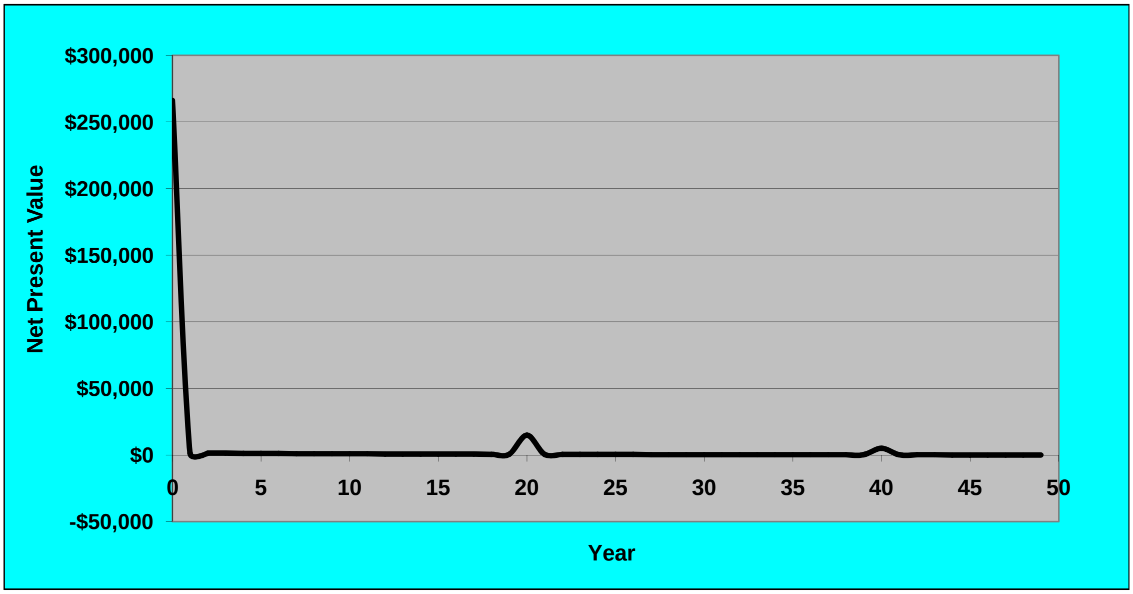
Whole Life Costs

Year	Discount Factor	Capital & Assoc. Costs	Regular Maint. Costs	Corrective & Infrequent Maint. Activities				Total Costs	Present Value of Costs	Cumulative Costs	
				Intermit. Facility Maint.	Sediment Removal	Other [User Entered]	Total Irregular Maint.			Cash	Present Value
Cash Sum ($)								$ 428,351	$ 312,452		
0	1.000	$ 266,250						$ 266,250	$ 266,250	$ 266,250	$ 266,250
1	0.948	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 1,510	$ 267,843	$ 267,760
2	0.898	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 1,432	$ 269,437	$ 269,192
3	0.852	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 1,357	$ 271,030	$ 270,549
4	0.807	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 1,286	$ 272,623	$ 271,835
5	0.765	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 1,219	$ 274,217	$ 273,054
6	0.725	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 1,156	$ 275,810	$ 274,210
7	0.687	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 1,095	$ 277,403	$ 275,305
8	0.652	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 1,038	$ 278,997	$ 276,343
9	0.618	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 984	$ 280,590	$ 277,327
10	0.585	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 933	$ 282,183	$ 278,260
11	0.555	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 884	$ 283,777	$ 279,144
12	0.526	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 838	$ 285,370	$ 279,982
13	0.499	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 794	$ 286,963	$ 280,777
14	0.473	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 753	$ 288,557	$ 281,530
15	0.448	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 714	$ 290,150	$ 282,243
16	0.425	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 676	$ 291,743	$ 282,920
17	0.402	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 641	$ 293,337	$ 283,561
18	0.381	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 608	$ 294,930	$ 284,169
19	0.362	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 576	$ 296,523	$ 284,745
20	0.343	$ -	$ 593	$ 1,000	$ 42,014	$ -	$ 43,014	$ 43,607	$ 14,945	$ 340,131	$ 299,690
21	0.325	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 518	$ 341,724	$ 300,208
22	0.308	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 491	$ 343,317	$ 300,699
23	0.292	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 465	$ 344,911	$ 301,164
24	0.277	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 441	$ 346,504	$ 301,604
25	0.262	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 418	$ 348,097	$ 302,022
26	0.249	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 396	$ 349,691	$ 302,418
27	0.236	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 375	$ 351,284	$ 302,794
28	0.223	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 356	$ 352,877	$ 303,150
29	0.212	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 337	$ 354,471	$ 303,487
30	0.201	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 320	$ 356,064	$ 303,806
31	0.190	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 303	$ 357,657	$ 304,110
32	0.180	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 287	$ 359,251	$ 304,397
33	0.171	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 272	$ 360,844	$ 304,669
34	0.162	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 258	$ 362,437	$ 304,927
35	0.154	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 245	$ 364,031	$ 305,172
36	0.146	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 232	$ 365,624	$ 305,404
37	0.138	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 220	$ 367,217	$ 305,623
38	0.131	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 208	$ 368,811	$ 305,832
39	0.124	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 197	$ 370,404	$ 306,029
40	0.117	$ -	$ 593	$ 1,000	$ 42,014	$ -	$ 43,014	$ 43,607	$ 5,122	$ 414,011	$ 311,151
41	0.111	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 177	$ 415,604	$ 311,329
42	0.106	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 168	$ 417,198	$ 311,497
43	0.100	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 159	$ 418,791	$ 311,656
44	0.095	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 151	$ 420,384	$ 311,807
45	0.090	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 143	$ 421,978	$ 311,951
46	0.085	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 136	$ 423,571	$ 312,086
47	0.081	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 129	$ 425,164	$ 312,215
48	0.077	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 122	$ 426,758	$ 312,337
49	0.073	$ -	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,593	$ 116	$ 428,351	$ 312,452
50	0.069	$ 1	$ 593	$ 1,000	$ -	$ -	$ 1,000	$ 1,594	$ 110	$ 429,945	$ 312,562

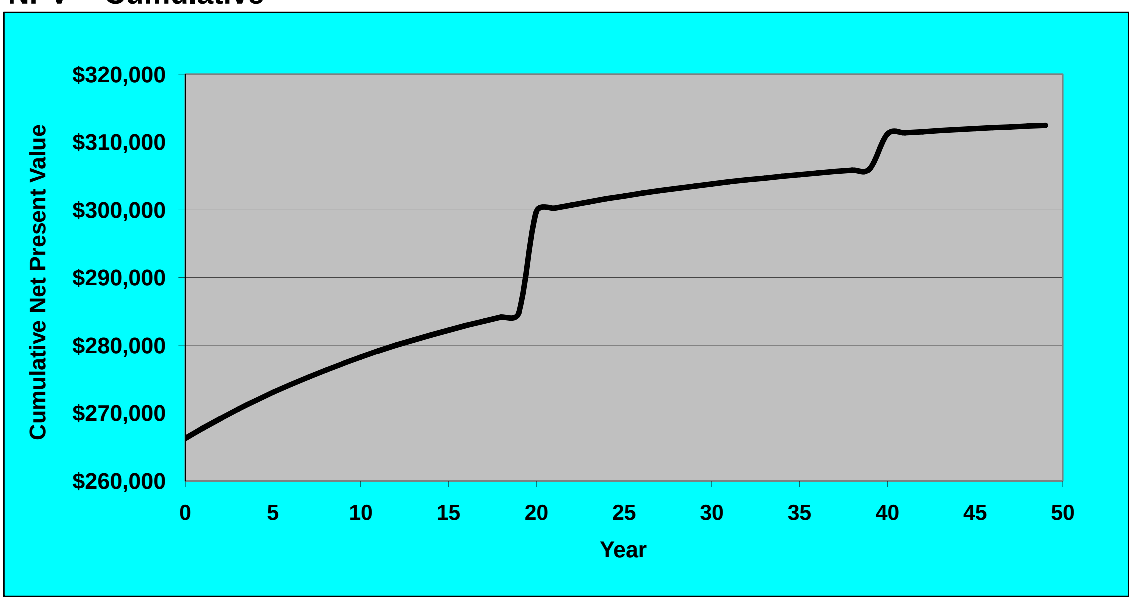
Retention Pond

Site Name:
Site Location:

Net Present Value over time



NPV - Cumulative



Swale

Site Name:

Site Location:

Design & Maintenance Options

WATERSHED CHARACTERISTICS	Unit	Model Default	User	Chosen option
Drainage Area (DA)	ac	2.00		2.00
Drainage Area Impervious Cover (IC)*	pct	40%		40%
Watershed Land Use Type *("R"-Residential; "C"-Commercial; "Ro"-Roads; "I"-Industrial)*		R		R

* Included since frequently used to calculate facility sizing.

DESIGN & MAINTENANCE OPTIONS	Unit	Model Default	User	Chosen Option
Choose Level of Maintenance *("H"=high; "M"=medium; "L"=low)*	-	M		M

WHOLE LIFE COST OPTIONS	Unit	Model Default	User	Chosen Option
Discount Rate	%	5.50		5.5

Swale

CAPITAL COSTS

Site Name:
Site Location:

Choose Capital Costing Option

A	Total Facility Cost	$ 16,500

"A" - Simple Cost based on Drainage Area
"B" - User-Entered Engineer's Estimate

Method A: Simple Cost based on Drainage Area

Cost based on Drainage Area	Cost per Acre of DA Treated		(Chosen option)
	Model Default	User	
Drainage Area (DA) (acres)	2.00		2.00
Base Facility Cost per acre DA*	$ 3,000		$ 3,000
Default Cost Adjustment for Smaller Projects**	2.20		2.20
Resulting Base Cost per acre DA	$ 6,600		$ 6,600
Base Facility Cost (rounded up to nearest $100)	$ 13,200		**$ 13,200**
Engineering & Planning (default = 25% of Base Cost)	$ 3,300		$ 3,300
Land Cost	$ 0		$ 0
Other Costs	$ 0		$ 0
Total Associated Capital Costs (e.g., Engineering, Land, etc.)			**$ 3,300**
Total Facility Cost	**$ 16,500**		**$ 16,500**

*** Base Facility Cost guidelines (circa Year 2005)**
Very High = $15,000/acre
High = $5,000/acre
Medium = $3,000/acre
Low = $1,000/acre
** Smaller projects generally incur higher unit costs for many components; factor added to adjust.
Suggestion: Use higher or lower Base Costs to reflect higher or lower regional construction costs.
Some jurisdictions already have cost relationships established; check to see if any available.

Method B: User-Entered Engineer's Estimate

Select from the following list, as applicable to the project or facility type; add items where necessary.

Total Facility Base Costs	Unit	Unit Cost	Quantity	Cost
Mobilization	LS			$ -
Clearing & Grubbing	AC			$ -
Excavation/Grading	CY			$ -
Dewatering	LS			$ -
Haul/Dispose of Excavated Material	CY			$ -
Sediment Pretreatment Struct. (e.g., inlet sump)	LF			$ -
Inflow Structure(s)	LS			$ -
Energy Dissipation Apron	LS			$ -
Overflow Structure (concrete or rock riprap)	CY			$ -
Revegetation/Erosion Controls	SY			$ -
Traffic Control	LS			$ -
Signage, Public Education Materials, etc.	LS			$ -
Other				$ -
Other				$ -
Other				$ -
Total Facility Base Cost				**$ -**
Associated Capital Costs	**Unit**	**Unit Cost**	**Quantity**	**Cost**
Project Management				$ -
Engineering: Preliminary				$ -
Engineering: Final Design				$ -
Topographic Survey				$ -
Geotechnical				$ -
Landscape Design				$ -
Land Acquisition (site, easements, etc.)				$ -
Utility Relocation				$ -
Legal Services				$ -
Permitting & Construction Inspection				$ -
Sales Tax				$ -
Contingency (e.g., 30%)				$ -
Total Associated Capital Costs				**$ -**
Total Facility Cost				**$ -**

Swale

Site Name:

Site Location:

M — **User entered MEDIUM maintenance level in Sheet 1.**

** Change on Sheet 1 if desired/applicable **

Maintenance Costs

User may enter lump sum here

Lookup ID	ROUTINE MAINTENANCE ACTIVITIES (Frequent, scheduled events)																					
	Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Inciden-tals Cost/Event ($)			Total cost per visit ($)		
		Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input
1.1	Inspection, Reporting & Information Management	36		36	2		2	1.0		1.0	40		40	30		30	0		0	140		140
1.2	Vegetation Management with Trash & Minor Debris Removal	12		12	4		4	2.0		2.0	30		30	60		60	0		0	480		480
1.3	*add additional activities if necessary*	0		0	0		0	0.0		0.0	0		0	0		0	0		0	0		0
1.4	*add additional activities if necessary*	0		0	0		0	0.0		0.0	0		0	0		0	0		0	0		0

Lookup ID	CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or > 3 yrs. betw. events)																					
	Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Inciden-tals Cost/Event ($)			Total cost per visit ($)		
		Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input
2.1	Corrective Maintenance	48		48	8		8	4.0		4.0	30		30	60		60	0		0	1,440		1,440
2.2	*add additional activities if necessary*	0		0	0		0	0.0		0.0	0		0	0		0	0		0	0		0
2.3	*add additional activities if necessary*	0		0	0		0	0.0		0.0	0		0	0		0	0		0	0		0

Note: For facilities judged to require larger or smaller amounts of maintenance (due to land area, etc.), consider multiplying the Model output in Column U by a multiplier (e.g., 120%) in Column V.
Another quick means of adjustment would be to multiply the number of Hours per Event by a multiplier in the User Input field.

Lookup Table Value

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Lookup ID	HIGH, MEDIUM, AND LOW (MINIMUM) MAINTENANCE COST TABLES																					
	Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Inciden-tals Cost/Event ($)			Total cost per visit ($)		
		Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
1.0	ROUTINE MAINTENANCE ACTIVITIES (Frequent, scheduled)																					
1.1	Inspection, Reporting & Information Management	36	36	12	2	2	2	1.0	1.0	2.0	15.00	40.00	50.00	30	30	30	0	0	0	90	140	260
1.2	Vegetation Management with Trash & Minor Debris Removal	36	12	1	4	4	4	2.0	2.0	2.0	15.00	30.00	30.00	60	60	60	0	0	0	360	480	480
1.3	*add additional activities if necessary*																					
1.4	*add additional activities if necessary*																					
2.0	CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or > 3 yrs. betw. events)																Cost per Cubic Yard Disposal					
2.1	Corrective Maintenance	120	48	24	8	8	8	4.0	4.0	4.0	15.00	30.00	30.00	60	60	60				960	1,440	1,440
2.2	*add additional activities if necessary*																					
2.3	*add additional activities if necessary*																					

Swale

Site Name:
Site Location:

Cost Summary

CAPITAL COSTS	Included in WLC Calculation			Total Cost	
	Model	User	Chosen option		
Total Facility Base Cost	Y		Y		$13,200
Total Associated Capital Costs (e.g., Engineering, Land, etc.)	Y		Y		$3,300
Capital Costs	Y		Y		**$16,500**

REGULAR MAINTENANCE ACTIVITIES	Included in WLC Calculation			Years between Events	Cost per Event	Total Cost per Year
	Model	User	Chosen option			
Inspection, Reporting & Information Management	Y		Y	3	$140	$47
Vegetation Management with Trash & Minor Debris Removal	Y		Y	1	$480	$480
add additional activities if necessary	Y		Y	0	$0	$0
add additional activities if necessary	Y		Y	0	$0	$0
Totals, Regular Maintenance Activities						**$527**

CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or >3yrs. betw. events)	Included in WLC			Years between Events	Cost per Event	Total Cost per Year
	Model	User	Chosen option			
Corrective Maintenance	Y		Y	4	$1,440	$360
add additional activities if necessary	Y		Y	0	$0	$0
add additional activities if necessary	Y		Y	0	$0	$0
Totals, Corrective & Infrequent Maintenance Activities						**$360**

Swale

Site Name:
Site Location:

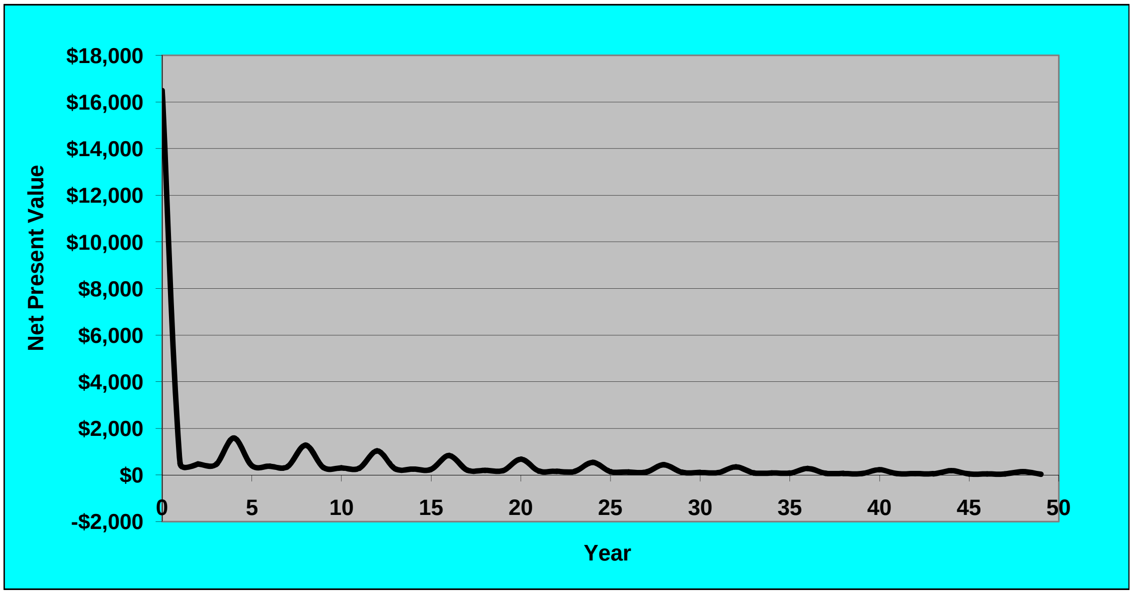
Whole Life Costs

Year	Discount Factor	Capital & Assoc. Costs	Regular Maint. Costs	Corrective Maint.	Total Costs	Present Value of Costs	Cumulative Costs	
							Cash	Present Value
Cash Sum ($)					**$ 59,587**	**$ 30,949**		
0	1.000	**$ 16,500**			$ 16,500	$ 16,500	$ 16,500	$ 16,500
1	0.948	$ -	**$ 527**	$ -	$ 527	$ 499	$ 17,027	$ 16,999
2	0.898	$ -	$ 527	$ -	$ 527	$ 473	$ 17,553	$ 17,472
3	0.852	$ -	$ 527	$ -	$ 527	$ 449	$ 18,080	$ 17,921
4	0.807	$ -	$ 527	$ 1,440	$ 1,967	$ 1,588	$ 20,047	$ 19,508
5	0.765	$ -	$ 527	$ -	$ 527	$ 403	$ 20,573	$ 19,911
6	0.725	$ -	$ 527	$ -	$ 527	$ 382	$ 21,100	$ 20,293
7	0.687	$ -	$ 527	$ -	$ 527	$ 362	$ 21,627	$ 20,655
8	0.652	$ -	$ 527	$ 1,440	$ 1,967	$ 1,281	$ 23,593	$ 21,937
9	0.618	$ -	$ 527	$ -	$ 527	$ 325	$ 24,120	$ 22,262
10	0.585	$ -	$ 527	$ -	$ 527	$ 308	$ 24,647	$ 22,571
11	0.555	$ -	$ 527	$ -	$ 527	$ 292	$ 25,173	$ 22,863
12	0.526	$ -	$ 527	$ 1,440	$ 1,967	$ 1,034	$ 27,140	$ 23,897
13	0.499	$ -	$ 527	$ -	$ 527	$ 263	$ 27,667	$ 24,160
14	0.473	$ -	$ 527	$ -	$ 527	$ 249	$ 28,193	$ 24,409
15	0.448	$ -	$ 527	$ -	$ 527	$ 236	$ 28,720	$ 24,645
16	0.425	$ -	$ 527	$ 1,440	$ 1,967	$ 835	$ 30,687	$ 25,480
17	0.402	$ -	$ 527	$ -	$ 527	$ 212	$ 31,213	$ 25,692
18	0.381	$ -	$ 527	$ -	$ 527	$ 201	$ 31,740	$ 25,892
19	0.362	$ -	$ 527	$ -	$ 527	$ 190	$ 32,267	$ 26,083
20	0.343	$ -	$ 527	$ 1,440	$ 1,967	$ 674	$ 34,233	$ 26,757
21	0.325	$ -	$ 527	$ -	$ 527	$ 171	$ 34,760	$ 26,928
22	0.308	$ -	$ 527	$ -	$ 527	$ 162	$ 35,287	$ 27,090
23	0.292	$ -	$ 527	$ -	$ 527	$ 154	$ 35,813	$ 27,244
24	0.277	$ -	$ 527	$ 1,440	$ 1,967	$ 544	$ 37,780	$ 27,788
25	0.262	$ -	$ 527	$ -	$ 527	$ 138	$ 38,307	$ 27,926
26	0.249	$ -	$ 527	$ -	$ 527	$ 131	$ 38,833	$ 28,057
27	0.236	$ -	$ 527	$ -	$ 527	$ 124	$ 39,360	$ 28,181
28	0.223	$ -	$ 527	$ 1,440	$ 1,967	$ 439	$ 41,327	$ 28,620
29	0.212	$ -	$ 527	$ -	$ 527	$ 111	$ 41,853	$ 28,732
30	0.201	$ -	$ 527	$ -	$ 527	$ 106	$ 42,380	$ 28,837
31	0.190	$ -	$ 527	$ -	$ 527	$ 100	$ 42,907	$ 28,938
32	0.180	$ -	$ 527	$ 1,440	$ 1,967	$ 355	$ 44,873	$ 29,292
33	0.171	$ -	$ 527	$ -	$ 527	$ 90	$ 45,400	$ 29,382
34	0.162	$ -	$ 527	$ -	$ 527	$ 85	$ 45,927	$ 29,467
35	0.154	$ -	$ 527	$ -	$ 527	$ 81	$ 46,453	$ 29,548
36	0.146	$ -	$ 527	$ 1,440	$ 1,967	$ 286	$ 48,420	$ 29,834
37	0.138	$ -	$ 527	$ -	$ 527	$ 73	$ 48,947	$ 29,907
38	0.131	$ -	$ 527	$ -	$ 527	$ 69	$ 49,473	$ 29,976
39	0.124	$ -	$ 527	$ -	$ 527	$ 65	$ 50,000	$ 30,041
40	0.117	$ -	$ 527	$ 1,440	$ 1,967	$ 231	$ 51,967	$ 30,272
41	0.111	$ -	$ 527	$ -	$ 527	$ 59	$ 52,493	$ 30,331
42	0.106	$ -	$ 527	$ -	$ 527	$ 56	$ 53,020	$ 30,386
43	0.100	$ -	$ 527	$ -	$ 527	$ 53	$ 53,547	$ 30,439
44	0.095	$ -	$ 527	$ 1,440	$ 1,967	$ 186	$ 55,513	$ 30,626
45	0.090	$ -	$ 527	$ -	$ 527	$ 47	$ 56,040	$ 30,673
46	0.085	$ -	$ 527	$ -	$ 527	$ 45	$ 56,567	$ 30,718
47	0.081	$ -	$ 527	$ -	$ 527	$ 43	$ 57,093	$ 30,760
48	0.077	$ -	$ 527	$ 1,440	$ 1,967	$ 151	$ 59,060	$ 30,911
49	0.073	$ -	$ 527	$ -	$ 527	$ 38	$ 59,587	$ 30,949
50	0.069	$ 1	$ 527	$ -	$ 528	$ 36	$ 60,114	$ 30,985

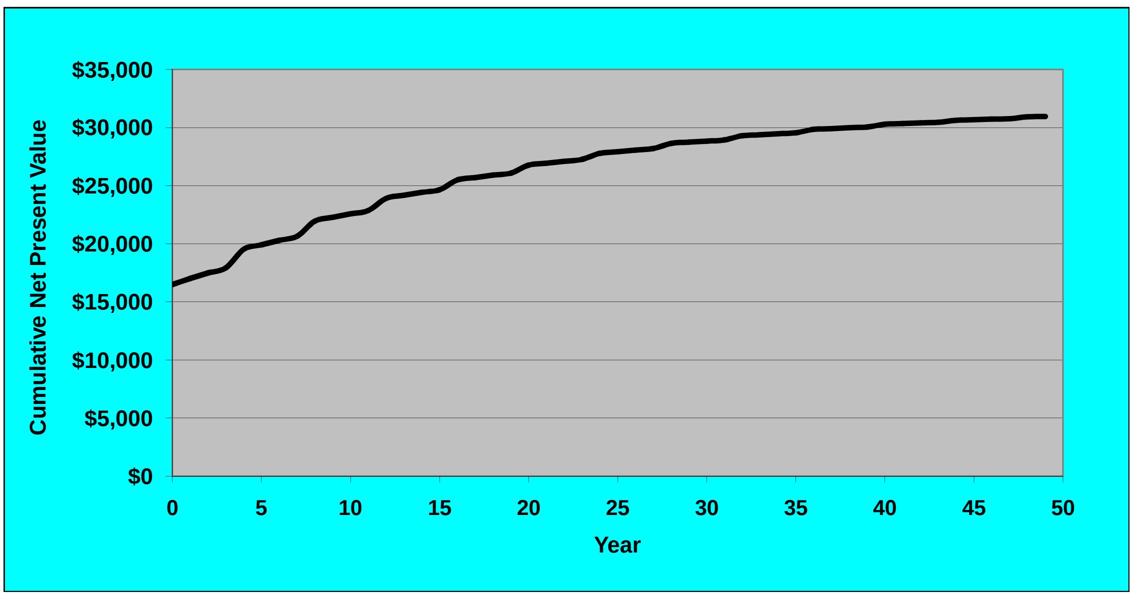
Swale

Site Name:
Site Location:

Net Present Value over time



NPV - Cumulative



SWALE DESIGN CRITERIA

Source: Texas Natural Resource Conservation Commission *Complying with the Edwards Aquifer Rules [Chapter 213 - Edwards Aquifer]: Technical Guidance on Best Management Practices.* June 1999. RG-348, pp. 3-42 to 3-45.

General Criteria (WSDOT, 1995) [Used as a model for criteria in other US jurisdictions]

(1) The swale should have a length that provides a minimum hydraulic residence time of at least 9 minutes. The maximum bottom width is 10 feet unless a dividing berm is provided (Figure 3.2). The depth of flow should not exceed 4 inches during a 1 inch/hour storm.

(2) The channel slope should be at least 1% and no greater than 5%.

(3) The swale can be sized as both a treatment facility for the design storm and as a conveyance system to pass the peak hydraulic flows of the 100-year storm if it is located “on-line.”

(4) The ideal cross-section of the swale should be a trapezoid. The side slopes should be no steeper than 3:1 (H:V).

(5) Roadside ditches should be regarded as significant potential swale/buffer strip sites and should be utilized for this purpose whenever possible.

(6) If flow is to be introduced through curb cuts, place pavement slightly above the elevation of the vegetated areas. Curb cuts should be at least 12 inches wide to prevent clogging.

(7) Swales must be vegetated in order to provide adequate treatment of runoff.

(8) It is important to maximize water contact with vegetation and the soil surface. For general purposes, select fine, close-growing, water-resistant grasses.

(9) Swales should generally not receive construction-stage runoff. If they do, presettling of sediments should be provided. Such swales should be evaluated for the need to remove sediments and restore vegetation following construction.

(10) If possible, divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.

Design Procedure

(1) Determine the peak flow rate to the swale from a storm producing a constant rainfall rate of 1 inch/hour.

(2) Determine the slope of the swale. This will be somewhat dependent on where the swale is placed. The slope should be at least 1% and should be no steeper than 5%.

(3) Select a swale shape. Trapezoidal is the most desirable shape; however, rectangular and triangular shapes can be used. The remainder of the design process assumes that a trapezoidal shape has been selected.

(4) Use Manning’s Equation to estimate the bottom width of the swale. Manning’s Equation for English units is as follows:

$Q = 1.49/n * A * R^{2/3} * S^{0.5}$
Where:
Q = flow (cfs)
A = cross-sectional area of flow (ft^2)
R = hydraulic radius of flow cross-section (ft)
S = longitudinal slope of swales (ft/ft)
n = Manning's roughness coefficient (0.20 for typical swale)

For a trapezoid, this equation cannot be directly solved for bottom width. However, for trapezoidal channels that are flowing very shallow the hydraulic radius can be set equal to the depth of flow. Using this assumption, the equation can be altered to:

$b = (0.134 * Q) / (y^{1.67} * S^{0.5}) - (z * y)$
Where:
b = bottom width
y = depth of flow
z = the side slope of the swale in the form of z:1

Typically the depth of flow is selected to be 4 inches (100 mm). It can be set lower but doing so will increase the bottom width. Sometimes when the flow rate is very low the equation listed above will generate a negative value for b. Since it is not possible to have a negative bottom width, the bottom width should be set to 2 feet when this occurs. Swales are limited to a maximum bottom width of 10 feet. If the required bottom width is greater than 10 feet, parallel swales should be used in conjunction with a device that splits the flow and directs the proper amount to each swale.

(5) Calculate the cross-sectional area of flow for the given channel using the calculated bottom width and the selected side slopes and depth.

(6) Calculate the velocity of flow in the channel using:

V = Q / A

If V is less than or equal to 1.0 ft/s, the swale will function correctly with the selected bottom width. Proceed to design step 7. If V is greater than 1 ft/s, the swale will not function correctly. Increase the bottom width, recalculate the depth using Manning's Equation and return to design step 5.

(7) Calculate the minimum swale length (L) using:

L(ft) = V(ft/s) x 540(s)

Where 540 seconds (9 minutes) is the minimum hydraulic residence time. Select a location where a swale with the calculated width and a length will fit. If the minimum length is not feasible within site constraints, the width of the swale should be increased so that the area of the swale is the same as if the calculated minimum length had been used.

(8) Select a vegetation cover suitable for the site.

(9) Determine the peak flow rate to the swale during the 100-year 24-hour storm. Using Manning's Equation, find the depth of flow (typically n = 0.04 during the 100-year flow). The depth of the channel should be 1 foot (300 mm) deeper than the depth of flow.

Residential Rain Garden

Site Name:

Site Location:

Date:

Design & Maintenance Options

WATERSHED CHARACTERISTICS	Unit	Model Default	User	Chosen option
Drainage Area (often roof area + paved area, square Feet) (DA)	sq ft	1000		1000
Garden Area (default is 20% of DA, Square Feet)	sq ft	200		200

DESIGN & MAINTENANCE OPTIONS	Unit	Model Default	User	Chosen Option
Installation (S = self or volunteer; P = professional)		P		P
Single house (S) or entire neighborhood (>100 homes, N)?		S		S
Choose Level of Maintenance *("H"=high, ornate garden; "M"=medium, standard garden; "L"=low, wild area)*	-	M		M

WHOLE LIFE COST OPTIONS	Unit	Model Default	User	Chosen Option
Discount Rate	%	5.50		5.5

Note: All worksheets, other than User Entered information, are locked to prevent unintentional changes to default values or formulas. To unlock, right-click on the tab of the worksheet you wish to unlock and select "unprotect".

Residential Rain Garden

CAPITAL COSTS

Site Name:
Site Location:
Date:

Choose Capital Costing Option

A	**Total Facility Cost**	**$**	**3,782**

"A" - Simple Cost based on Drainage Area
"B" - User-Entered Engineer's Estimate

Installation type Chosen: **Professional Installation** / **Single House**

Method A: Simple Cost based on Drainage Area

Cost based on Drainage Area	Model Default		User	Chosen Option	
Drainage Area (DA) (Square Feet)		1000			1,000
Garden Area (Assumed 20% of DA, Square Feet)		200			200
Cost of Rain garden per Square Foot	$	16.05		$	16.05
Base Facility Cost of Rain garden	**$**	**3,210**		**$**	**3,210**
Landscape Design Costs	$	96		$	96
Resulting Base Cost of Rain garden (rounded up to nearest $10)	$	3,310		$	3,310
Establishment Costs, 1st year maintenance	$	476		$	476
Discount for Neighborhood Installations	$	-		$	-
Total Facility Cost	**$**	**3,782**		**$**	**3,782**

Method B: User-Entered Engineer's Estimate (Not applicable if self-installed)

Select from the following list, as applicable to the project or facility type; add items where necessary.

Total Facility Base Costs	Unit	Unit Cost	Quantity	Cost	
Mobilization	LS			$	-
Clearing & Grubbing	AC			$	-
Excavation/Grading	CY			$	-
Dewatering	LS			$	-
Haul/Dispose of Excavated Material	CY			$	-
Sediment Pretreatment Struct.	LS			$	-
Impervious Lining	SY			$	-
Underdrain to Conventional Storm drain	LS			$	-
Soil Amendment, Engineered Medium Backfill	CY			$	-
Energy Dissipation Apron/ Inflow Structures	LS			$	-
Overflow Structure (concrete or rock riprap, optional)	CY			$	-
Landscaping Materials and Labor	SY			$	-
Other				$	-
Other				$	-
Other				$	-
Total Facility Base Cost				**$**	**-**
Associated Capital Costs	**Unit**	**Unit Cost**	**Quantity**	**Cost**	
Landscape Design				$	-
Utility Relocation				$	-
Permitting & Construction Inspection				$	-
Sales Tax				$	-
Contingency (e.g., 30%)				$	-
Other				$	-
Other				$	-
Other				$	-
Total Associated Capital Costs				**$**	**-**
Total Facility Cost				**$**	**-**

Residential Rain Garden

Site Name:

Site Location:

Date:

M	**User entered 'MEDIUM' maintenance level in Sheet 1.**
P	**User entered 'Professional' installation type in Sheet 1.**
S	**User entered 'Single Home' installation type in Sheet 1.**

** Change on Sheet 1 if desired/applicable **

Maintenance Costs

User may enter lump sum here

ROUTINE MAINTENANCE ACTIVITIES (Frequent, scheduled events)																					
Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Inciden-tals Cost/Event ($)			Total cost per visit ($)		
	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input
Vegetation Management	12		12.0	2		2.00	1		1.0	31		31.00	0		0.00	10		10.00	72		72
add additional activities if necessary	0		0.0	0		0.00	0		0.0	0		0.00	0		0.00	0		0.00	0		0
add additional activities if necessary	0		0.0	0		0.00	0		0.0	0		0.00	0		0.00	0		0.00	0		0

CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or > 3 yrs. betw. events)																					
Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Inciden-tals Cost/Event ($)			Total cost per visit ($)		
	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input
Replace mulch	36		36.0	3		3.00	2		2.0	31		31.00	0		0.00	150		150.00	336		336
Till Soil	60		60.0	2		2.00	2		2.0	31		31.00	50		50.00	0		0.00	224		224
add additional activities if necessary	0		0.0	0		0.00	0		0	0		0.00	0		0.00	0		0.00	0		0
add additional activities if necessary	0		0.0	0		0.00	0		0.0	0		0.00	0		0.00	0		0.00	0		0

Note: For facilities judged to require larger or smaller amounts of maintenance (due to land area, etc.), consider multiplying the Model output in Column U by a multiplier (e.g., 120%) in Column V.
Another quick means of adjustment would be to multiply the number of Hours per Event by a multiplier in the User Input field.

Lookup Table Value

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
HIGH, MEDIUM, AND LOW (MINIMUM) MAINTENANCE COST TABLES																						
Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Inciden-tals Cost/Event ($)			Total cost per visit ($)			
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Self	Low	Med	High
ROUTINE MAINTENANCE ACTIVITIES (Frequent, scheduled)																						
Vegetation Management	36	12	1	0	2	2	0.0	1.0	2.0	0.00	31.00	45.00	0	0	60	0	10	20	10	0	72	320
add additional activities if necessary																				0	0	0
add additional activities if necessary																				0	0	0
CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or > 1 yrs. betw. events)																						
Replace mulch	60	36	12	2	3	4	2.0	2.0	2.0	0.00	31.00	45.00	0	0	0	150	150	150	150	150	336	510
Till Soil	120	60	48	2	2	2	2.0	2.0	2.0	0.00	31.00	45.00	50	50	50	0	0	0	50	100	224	280
add additional activities if necessary																				0	0	0
add additional activities if necessary																				0	0	0

Residential Rain Garden

M	User entered 'MEDIUM' maintenance level in Sheet 1.
P	User entered 'Professional' installation type in Sheet 1.
S	User entered 'Single Home' installation type in Sheet 1.
A	User entered 'Option A' Capital Cost Option in Sheet 2.

Site Name:

Site Location:

Date:

Cost Summary

CAPITAL COSTS	Total Cost		Included in WLC Calculation		
			Model	User	Chosen option
Base Cost of Garden (rounded up to nearest $100)		$ 3,210	$ 3,210		$ 3,210
Associated Capital Costs		$ 572	$ 572		$ 572
Capital Costs			$ 3,782		$ 3,782

REGULAR MAINTENANCE ACTIVITIES	months between events	Cost per Event	Total Cost per Year	Included in WLC Calculation		
				Model	User	Chosen option
Vegetation Management	12	$72	$72	$72		$ 72.00
add additional activities if necessary	0	$0	0	$0		$ -
add additional activities if necessary	0	$0	0	$0		$ -
Totals, Regular Maintenance Activities				**$72**		$ 72.00

CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or >3yrs. betw. events)	Years between Events	Cost per Event	Total Cost per Year Equivalent	Included in WLC		
				Model	User	Chosen option
Replace mulch	3	$336	$112	$112		$ 112.00
Till Soil	5	$224	$45	$45		$ 44.80
add additional activities if necessary	0	$0	$0	$0		$ -
Totals, Corrective & Infrequent Maintenance Activities				$157		$ 156.80

Residential Rain Garden

M	User entered 'MEDIUM' maintenance level in Sheet 1.
P	User entered 'Professional' installation type in Sheet 1.
S	User entered 'Single Home' installation type in Sheet 1.

Site Name:

Site Location:
Date:

Whole Life Costs

Year	Discount Factor	Capital & Assoc. Costs	Regular Maint. Costs	Corrective Maint.	Total Costs	Present Value of Costs	Cumulative Costs		
							Cash	Present Value	Discounted Costs Per Year
Cash Sum ($)					**$ 15,070**	**$ 7,533**			
0	1.000	**$ 3,782**	$ 72		$ 3,854	$ 3,854	$ 3,854	$ 3,854	$ 7,533
1	0.948	$ -	$ 72	$ -	$ 72	$ 68	$ 3,926	$ 3,922	$ 3,679
2	0.898	$ -	$ 72	$ -	$ 72	$ 65	$ 3,998	$ 3,987	$ 3,611
3	0.852	$ -	$ 72	$ 336	$ 408	$ 347	$ 4,406	$ 4,334	$ 3,546
4	0.807	$ -	$ 72	$ -	$ 72	$ 58	$ 4,478	$ 4,392	$ 3,199
5	0.765	$ -	$ 72	$ 224	$ 296	$ 226	$ 4,774	$ 4,619	$ 3,141
6	0.725	$ -	$ 72	$ 336	$ 408	$ 296	$ 5,182	$ 4,915	$ 2,914
7	0.687	$ -	$ 72	$ -	$ 72	$ 49	$ 5,254	$ 4,964	$ 2,618
8	0.652	$ -	$ 72	$ -	$ 72	$ 47	$ 5,326	$ 5,011	$ 2,569
9	0.618	$ -	$ 72	$ 336	$ 408	$ 252	$ 5,734	$ 5,263	$ 2,522
10	0.585	$ -	$ 72	$ 224	$ 296	$ 173	$ 6,030	$ 5,436	$ 2,270
11	0.555	$ -	$ 72	$ -	$ 72	$ 40	$ 6,102	$ 5,476	$ 2,097
12	0.526	$ -	$ 72	$ 336	$ 408	$ 215	$ 6,510	$ 5,691	$ 2,057
13	0.499	$ -	$ 72	$ -	$ 72	$ 36	$ 6,582	$ 5,727	$ 1,842
14	0.473	$ -	$ 72	$ -	$ 72	$ 34	$ 6,654	$ 5,761	$ 1,806
15	0.448	$ -	$ 72	$ 560	$ 632	$ 283	$ 7,286	$ 6,044	$ 1,772
16	0.425	$ -	$ 72	$ -	$ 72	$ 31	$ 7,358	$ 6,075	$ 1,489
17	0.402	$ -	$ 72	$ -	$ 72	$ 29	$ 7,430	$ 6,103	$ 1,459
18	0.381	$ -	$ 72	$ 336	$ 408	$ 156	$ 7,838	$ 6,259	$ 1,430
19	0.362	$ -	$ 72	$ -	$ 72	$ 26	$ 7,910	$ 6,285	$ 1,274
20	0.343	$ -	$ 72	$ 224	$ 296	$ 101	$ 8,206	$ 6,387	$ 1,248
21	0.325	$ -	$ 72	$ 336	$ 408	$ 133	$ 8,614	$ 6,519	$ 1,147
22	0.308	$ -	$ 72	$ -	$ 72	$ 22	$ 8,686	$ 6,541	$ 1,014
23	0.292	$ -	$ 72	$ -	$ 72	$ 21	$ 8,758	$ 6,562	$ 992
24	0.277	$ -	$ 72	$ 336	$ 408	$ 113	$ 9,166	$ 6,675	$ 971
25	0.262	$ -	$ 72	$ 224	$ 296	$ 78	$ 9,462	$ 6,753	$ 858
26	0.249	$ -	$ 72	$ -	$ 72	$ 18	$ 9,534	$ 6,771	$ 780
27	0.236	$ -	$ 72	$ 336	$ 408	$ 96	$ 9,942	$ 6,867	$ 762
28	0.223	$ -	$ 72	$ -	$ 72	$ 16	$ 10,014	$ 6,883	$ 666
29	0.212	$ -	$ 72	$ -	$ 72	$ 15	$ 10,086	$ 6,898	$ 650
30	0.201	$ -	$ 72	$ 560	$ 632	$ 127	$ 10,718	$ 7,025	$ 635
31	0.190	$ -	$ 72	$ -	$ 72	$ 14	$ 10,790	$ 7,039	$ 508
32	0.180	$ -	$ 72	$ -	$ 72	$ 13	$ 10,862	$ 7,052	$ 495
33	0.171	$ -	$ 72	$ 336	$ 408	$ 70	$ 11,270	$ 7,121	$ 482
34	0.162	$ -	$ 72	$ -	$ 72	$ 12	$ 11,342	$ 7,133	$ 412
35	0.154	$ -	$ 72	$ 224	$ 296	$ 45	$ 11,638	$ 7,178	$ 400
36	0.146	$ -	$ 72	$ 336	$ 408	$ 59	$ 12,046	$ 7,238	$ 355
37	0.138	$ -	$ 72	$ -	$ 72	$ 10	$ 12,118	$ 7,248	$ 295
38	0.131	$ -	$ 72	$ -	$ 72	$ 9	$ 12,190	$ 7,257	$ 285
39	0.124	$ -	$ 72	$ 336	$ 408	$ 51	$ 12,598	$ 7,308	$ 276
40	0.117	$ -	$ 72	$ 224	$ 296	$ 35	$ 12,894	$ 7,343	$ 225
41	0.111	$ -	$ 72	$ -	$ 72	$ 8	$ 12,966	$ 7,351	$ 191
42	0.106	$ -	$ 72	$ 336	$ 408	$ 43	$ 13,374	$ 7,394	$ 183
43	0.100	$ -	$ 72	$ -	$ 72	$ 7	$ 13,446	$ 7,401	$ 140
44	0.095	$ -	$ 72	$ -	$ 72	$ 7	$ 13,518	$ 7,408	$ 132
45	0.090	$ -	$ 72	$ 560	$ 632	$ 57	$ 14,150	$ 7,464	$ 126
46	0.085	$ -	$ 72	$ -	$ 72	$ 6	$ 14,222	$ 7,471	$ 69
47	0.081	$ -	$ 72	$ -	$ 72	$ 6	$ 14,294	$ 7,476	$ 63
48	0.077	$ -	$ 72	$ 336	$ 408	$ 31	$ 14,702	$ 7,508	$ 57
49	0.073	$ -	$ 72	$ -	$ 72	$ 5	$ 14,774	$ 7,513	$ 26
50	0.069	$ -	$ 72	$ 224	$ 296	$ 20	$ 15,070	$ 7,533	$ 20

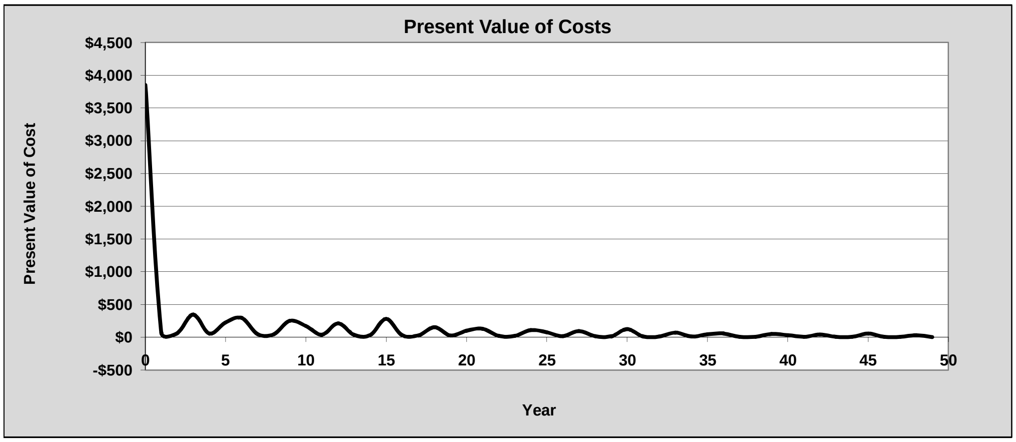
Residential Rain Garden

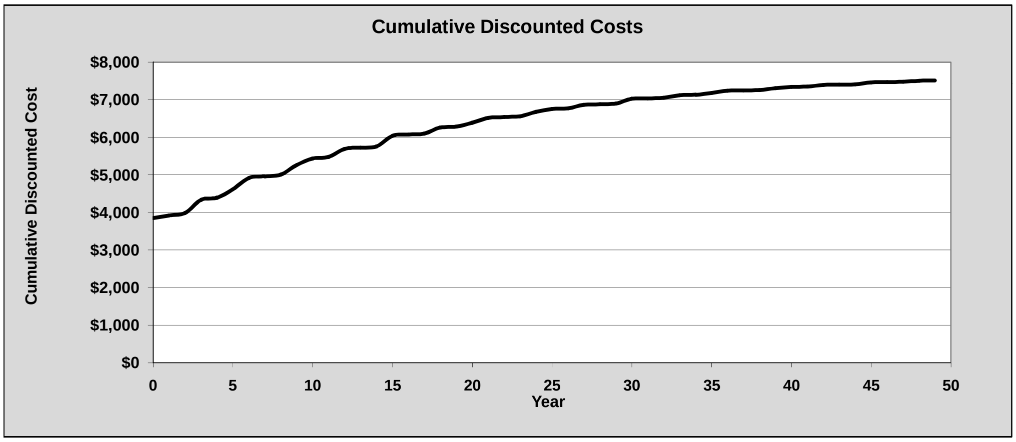
Site Name:

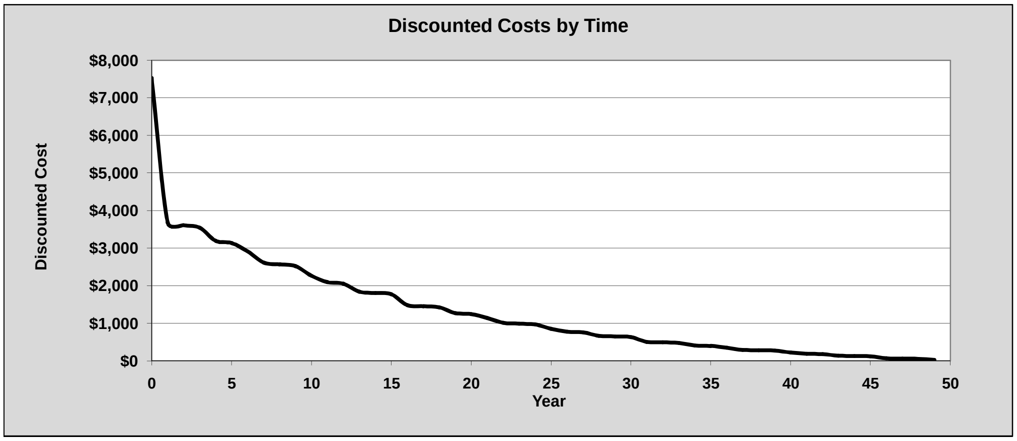
Site Location:

Date:

M	User entered 'MEDIUM' maintenance level in Sheet 1.
P	User entered 'Professional' installation type in Sheet 1.
S	User entered 'Single Home' installation type in Sheet 1.







Residential Rain Gardens Reference Sheet

Residential Rain Gardens are defined as small, vegetated basins designed to capture and utilize all precipitation/runoff from small events (i.e. 2-year storm) and serve as a detention facilities for larger events (i.e. 5-year storm and greater). These basins are often fed by down-spouts concentrating runoff from residential roofs or from collection areas near driveways and other paved surfaces associated with a single residence.

Design Assumptions for Default Cost Calculations:

-- Drainage area is assumed to be all impervious surfaces on a residential lot including roofs, driveways, walkways, patios, etc. (Kassulke (2003), Edgewood College (2003)).
-- The size of the rain garden should be 20% of this area, in square feet. Default assumes 1000 square foot drainage area and 200 square foot garden area (Kassulke (2003) & Edgewood College (2003)).
-- Default assumes 2.5 ft media depth. The Underdrain would lie in a trench below this (Jame's County (2008), Belan & Otto (2004)).
-- Overflow structures are the preferred method of draining excess inflow to a Residential Rain garden, especially with "Self" installation.
-- If required, underdrain is a 4" perforated pipe under garden and 4" drain pipe would travel a maximum of 25 ft to a street or storm drain (MDE 2000).
-- If installed in construction stage of new, large development, professional installation costs can be reduced up to 48% by economy of scale (EPA 2008).

Table 1: Summary of Residential Rain Garden Capital Cost Estimates. All costs assume modifying existing yards except EPA (2008) and are adjusted to 2008.

Source	Project Name	Location	Cost per Garden Area, Self Installation (per sq ft of garden)	Cost per Garden Area, Professionally Installed (per sq ft of garden area)	"Average garden size (sq ft)"
Belan & Otto (2004)	Summary of Concept	Great Lakes	unknown	unknown	70
Edgewood College (2003)	10 Steps to Building a Rain Garden	Wisconsin	$2.90-$4.60	$12.70 - $15.00	unknown
Kassulke (2003):	A Run on Rain Gardens	Wisconsin	$3.50-$5.80	$11.50 - $13.90	300
EPA 2008	Bioretention Costs	General	$3.00-$4.00	$10.00-$40.00	unknown
Jame's City County (2008)	Rain Garden Guide	Virginia	$0.50-$0.75	$10.00	150
Lincoln (2008)	Alternate Stormwater BMP'S	Lincoln, NE	$2.00-$8.00	$8.00-$14.00	unknown
RS Means 100* Estimate of Elaborate Garden		Salt Lake City, UT	$8.83	$16.63	unknown
	Average (2008 $)		**$5.15**	**$16.05**	**173**

* See users guide for suggestions on how to adjust RS Means 100 to local costs.

Table 2: Estimated Costs for an Engineered and Professionally Installed 200 sf Rain garden Using RS Means 100 Cost Data (Construction Control Corp., 2007).

Cost Item	QTY	Unit	Unit Cost	Cost
Mobilization	1	LS	$ 300.00	$ 300
Clearing & Grubbing	200	SF	$ 0.59	$ 118
Excavation/Grading	200	SF	$ 0.50	$ 100
Dewatering				$ -
Haul/Dispose of Excavated Material	200	SF	$ 0.89	$ 178
Sediment Pretreatment Struct.				$ -
Lining	200	SF	$ 0.45	$ 90
Underdrain to Conventional Storm drain	35	LF	$ 15.68	$ 549
Soil Amendment, Engineered Medium Backfill	266.00	CF	$ 1.11	$ 296
Energy Dissipation Apron/ Inflow Structures	0.25	EA	$ 650.00	$ 163
Overflow Structure (concrete or rock riprap, optional)	0.25	EA	$ 650.00	$ 163
Irrigation	200	SF	$ 0.55	$ 110
Topsoil	200	CY	$ 0.81	$ 163
Ornamental Grasses	10	EA	$ 15.65	$ 157
Shrubs	16	EA	$ 25.00	$ 400
Annuals	80	EA	$ 1.95	$ 156
Trees	1	EA	$ 200.00	$ 200
Wetlands Plantings	40	SF	$ 0.89	$ 36
Bark Mulch	200	SF	$ 0.75	$ 150
Associated Capitol Costs				$ -
Landscape Design Costs				$ -
Contingency Costs				$ -
Other				$ -
Other				$ -
Other				$ -
Total Facility Base Cost				**$ 3,326**
Cost Per Square Foot of Elaborate Garden				**$ 16.63**
Cost per Square Foot of a More Basic Garden (without underdrain, lining, engineered backfill, or engineered inflow and outflow structures).				**$ 8.83**

*Professionally installed garden including all discussed options plus ornate landscaping. This includes: underdrain, engineered growth medium back-fill, engineered inflow and outflow structures, impervious liner, and decorative landscaping.

Table 3: Maintenance Cost and Activities Reference Chart:

Source	Item	Cost	Notes
Home Depot	Soil Tiller Rental	50/4hr	Min 4 Hour Rental
RS Means	Labor Costs	31/hr	Mid-Range Labor Cost
RS Means	Bark Mulch	0.75/sf	

Residential Rain Garden References:

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Maryland Department of the Environment (MDE), 2000. 2000 Maryland Stormwater Design Manual, Appendix B-3 prepared by the Center for Watershed Protection and the Maryland Department of the Environment, Water Management Administration, Baltimore, MD.

R. S. Means estimate compiled by Construction Control Corporation, Salt Lake City, UT.

Source	Summary
Belan & Otto (2004)	American Rivers provides an excellent general overview for many bioretention items that include basic technical, design and cost information. The only technical or cost information applied to this tool is the average garden size.
Edgewood College (2003)	This article provides a step-by-step design approach for home owners interested in installing a rain garden and is an excellent over-view of small-scale bio-retention. Expected installation cost for self installation and professional installation is given.
Kassulke (2003):	The newspaper article provides a good summary of benefits of small-scale bioretention, and gives important technical design information. Design parameters suggested include: garden size to be 25%-30% of roof area (15%-20% for sandy soils); gutter redirection to garden, and cost of $3-$5 per sf for self installation and $10 - $12 per sf for professional installation.
EPA 2008	This web page suggests cost for self installation is $3.00-$4.00/ sf of garden area and $10.00-$40.00 per sf of garden area for self and professional installation, respectively. Technical data is reported on a different web page in the LID Center web page. Cost breakdown for self installation is 88% construction and materials, 2.5% in planning, 9.5% design. For Professional costs, 11% in design, 78% construction, 3% planning, and 8% close-out costs. Also, a savings of 50% per garden is suggested when rain gardens are included in the initial design of a new development of 100 houses or more.
Jame's City County (2008)	This Pamphlet includes design approaches and guidelines for residents interested in installing their own rain gardens. Great general overview of small-scale bioretention. Design guidelines include: 150 sf average garden size and 24"-30" depth in addition to materials and location suggestions. Cost information reported include: $.50 - $0.75 per sf for self-installed gardens and $10 for professional installations with the comment that costs can much higher depending on landscape options.
Lincoln (2008)	City of Lincoln, NE, reports general design considerations and a cost of $2 -$14. Cost variation is reported as a function of plant age established - less for sees and more for large, older plants.
MDE 2000	Referenced is the technical details of bioretention installations described in a larger Maryland Dept. of Environment, technical report. Design details give include: pipe diameter for underdrains, plant selection, depth and type of growth media.
RS Means 100* Estimate of Elaborate Garden	An RS Means based cost estimation for a rain garden that includes an underdrain, fabric liner, backfilled with low-density engineered growth media, and planted extensively with a large variety of ornate vegetation. This represents the high end of cost so that users can see costs of all potential aspects of installing a rain garden.

* See users guide for suggestions on how to adjust RS Means 100 to local costs.

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